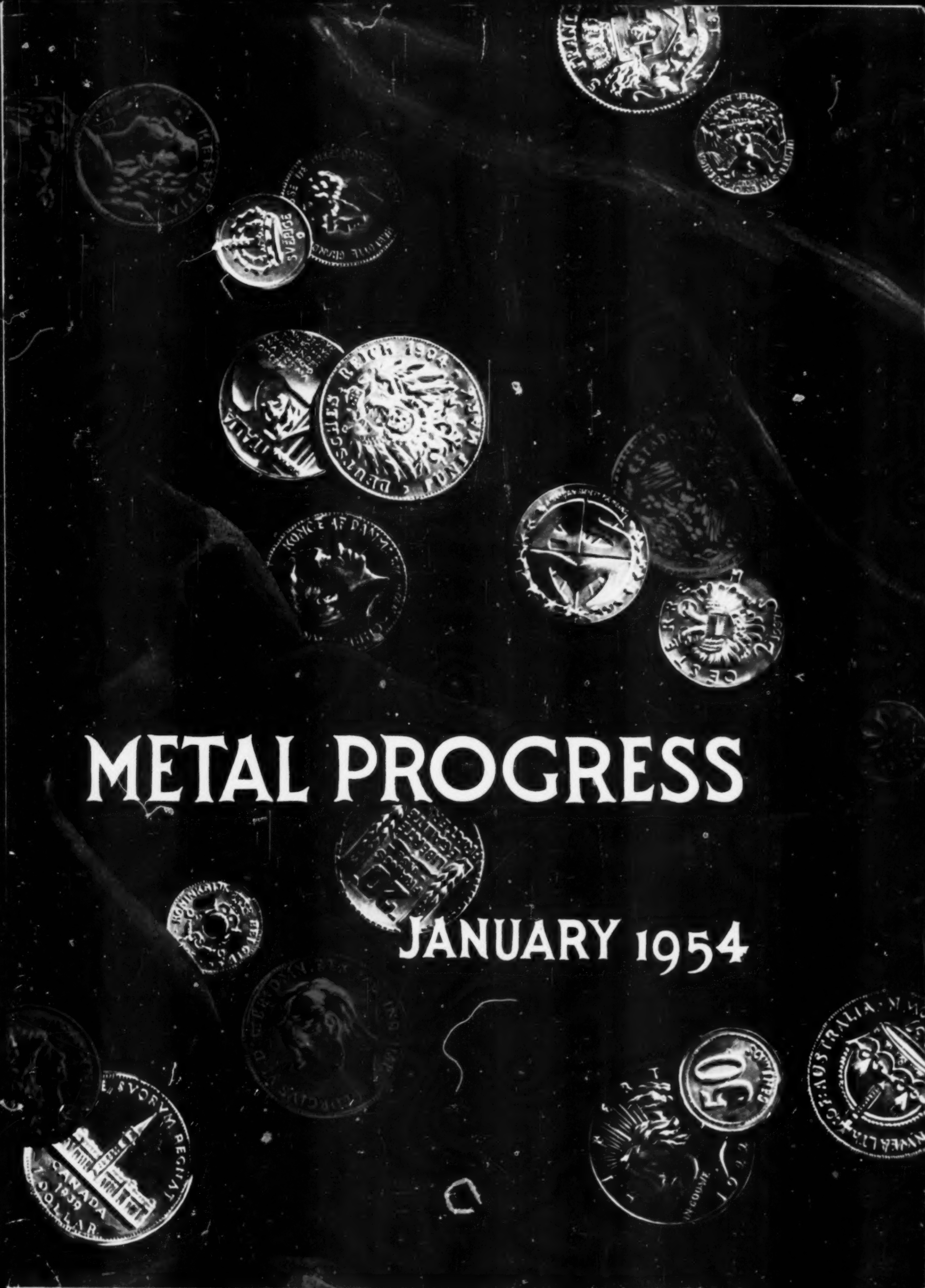

METAL PROGRESS

JANUARY 1954

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Cover by Glenn Imhoff

Engineering Articles

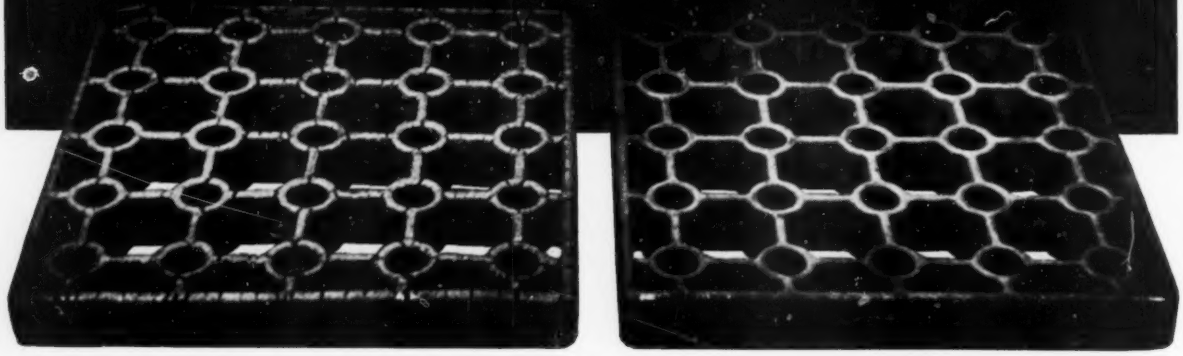
Critical Points

Correspondence

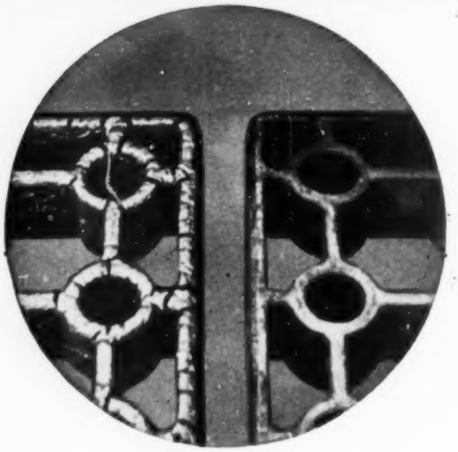
Digests of Important Articles

Departments

ONCE THEY WERE TWINS



... but identical service caused one to fail in 10 months ... while the other still serves *after 33 months!*



The heat treat trays shown above were part of an order supplied to a large automotive manufacturer by Electro-Alloys. *On the left* is a tray of standard analysis (35% Ni.—15% Cr.) which had been specified and used by the customer for some time. *On the right* is a tray of special analysis—THERMALLOY* "58B"—recommended by our metallurgists after careful study of the job requirements.

At our suggestion, a split order was placed on a trial basis. The pictures, taken after 10 months in carburizing service followed by an oil quench, tell their own story. Standard trays (left) had failed completely. They were badly checked and showed "growth" of as much as ⅜ of an inch on one dimension. Trays of THERMALLOY "58B" (right)—with exactly the same amount and kind of service—barely showed signs of use. There was no checking or cracking and "growth" was scarcely measurable. In fact, we just checked this manufacturer again ... and the same THERMALLOY "58B" tray is still in service *after 33 months.*

Here's proof that expert metallurgical knowledge *can* make a substantial difference in the life of heat treat parts. To put such knowledge to work for you, just phone your nearest Electro-Alloys office, or write Electro-Alloys Division, 5002 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN **Brake Shoe** COMPANY

ELECTRO-ALLOYS DIVISION

ELYRIA, OHIO

As I was saying...

HAPPY NEW YEAR to all of you from all of us! It's a sincere wish that this '54 will be better, more prosperous and happier than any year that has passed. Most of all, happiness is to be desired because when you're happy everything is bound to go well – and we know it will.

This first column of the New Year sees the writer with increased space over the previous half page. A relocation of the table of contents (placing it where you can find it) has placed added responsibilities on my pen to fill the new two-thirds page. I can only hope, with you, that Providence will fill my pen with good stuff and "let the ink run out when I've rit enough".

I'm happy to say that the first definite information about the European Technical Societies Congress, for which A.S.M. has accepted the invitation, can now be given. The Congress will open in London Wednesday, June 1, 1955, and close in Paris, June 19 or 20. The first sessions will be held in London, the second in Düsseldorf, and the final sessions in Paris. (If you are busy, you may wish to fly over and back, for a total absence of only three weeks; travel by boat both ways requires a month.) Plants and points of interest in the countries to be visited will be on a group-tour basis.

No special group movement is planned at the present time for the America-to-Europe passage. The choice of time, mode and type of accommodations will be determined by individual tastes and wishes.

Many may wish to extend their stay beyond the 18 days of the Congress so as to visit other countries in Europe or return for a more leisurely visit to one of the countries on the Congress tour. We have been assured that every possible assistance in arranging such extra trips before or after the Congress will be given.

I know our European friends can be counted on to do their usual thorough and skillful planning job so that you will be forever happy and thankful that you were privileged to attend the Congress.

What about the cost? We don't know yet, but costs are being studied by the European Committee. Until the definite itinerary in England, Germany and France is determined the expense can only be estimated. Nevertheless, here's a rough plan for figuring expenses of the trip. (1) You may inquire from Cook's or American Express or any registered travel bureau for round-trip fares from your embarkation point to Europe via air, all classes, or by ship, all classes – fast, slow, deluxe, first, tourist, cabin. (2) Established travel agencies will inform you that on group tours the total cost should be about $25 per day per person for all expenses except personal items. For any post-tour, if you are not traveling in a party, the daily cost will be slightly higher.

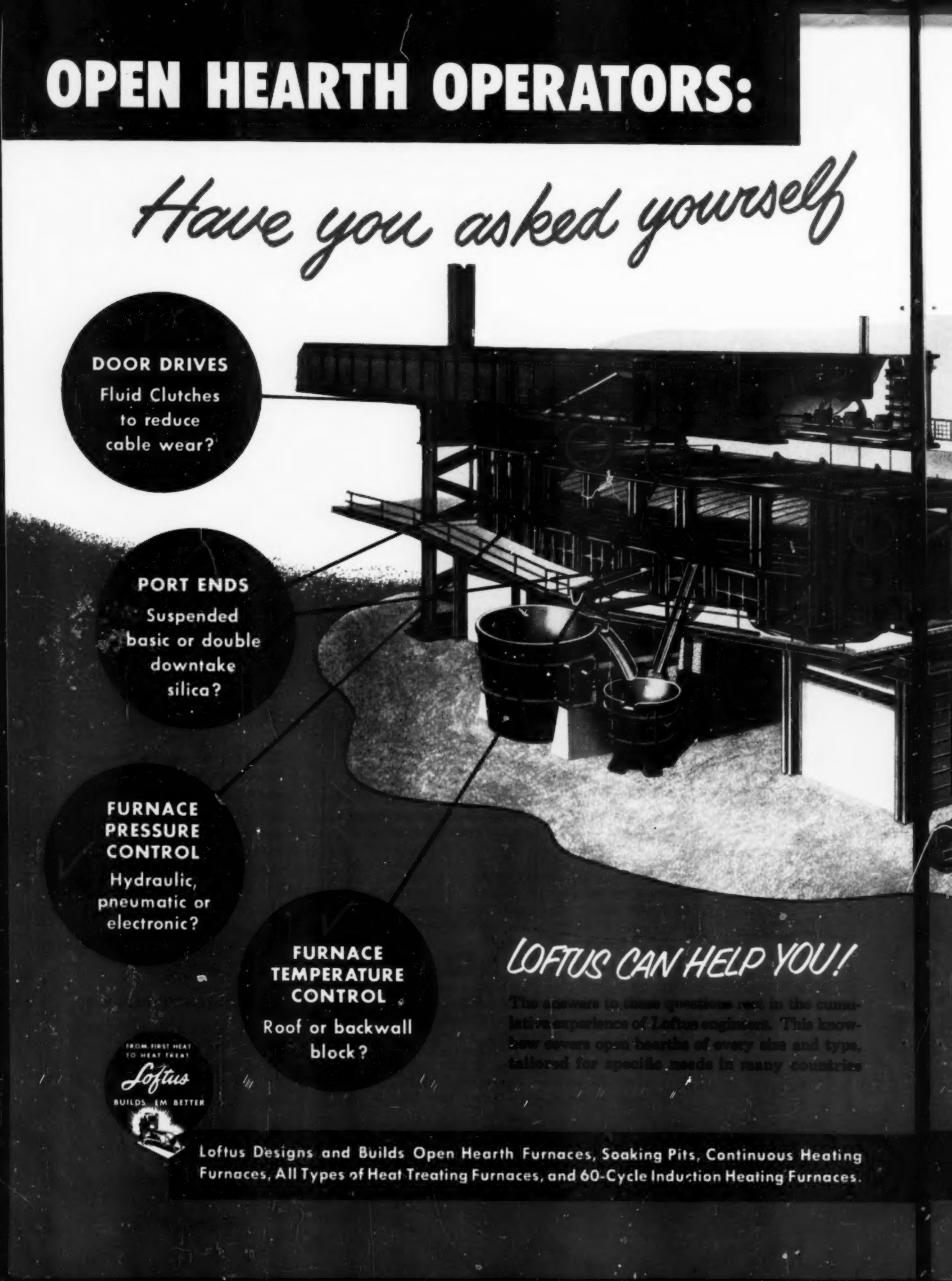
Hey, Mr. ASMer, do you want your name written there? Where? On the ASM list to receive immediate information about the European Congress as the plans develop, about the program, the plants to be visited, the costs, and other details. Then send your request to:

A.S.M. to Europe in 1955
7301 Euclid Ave., Cleveland 3, Ohio

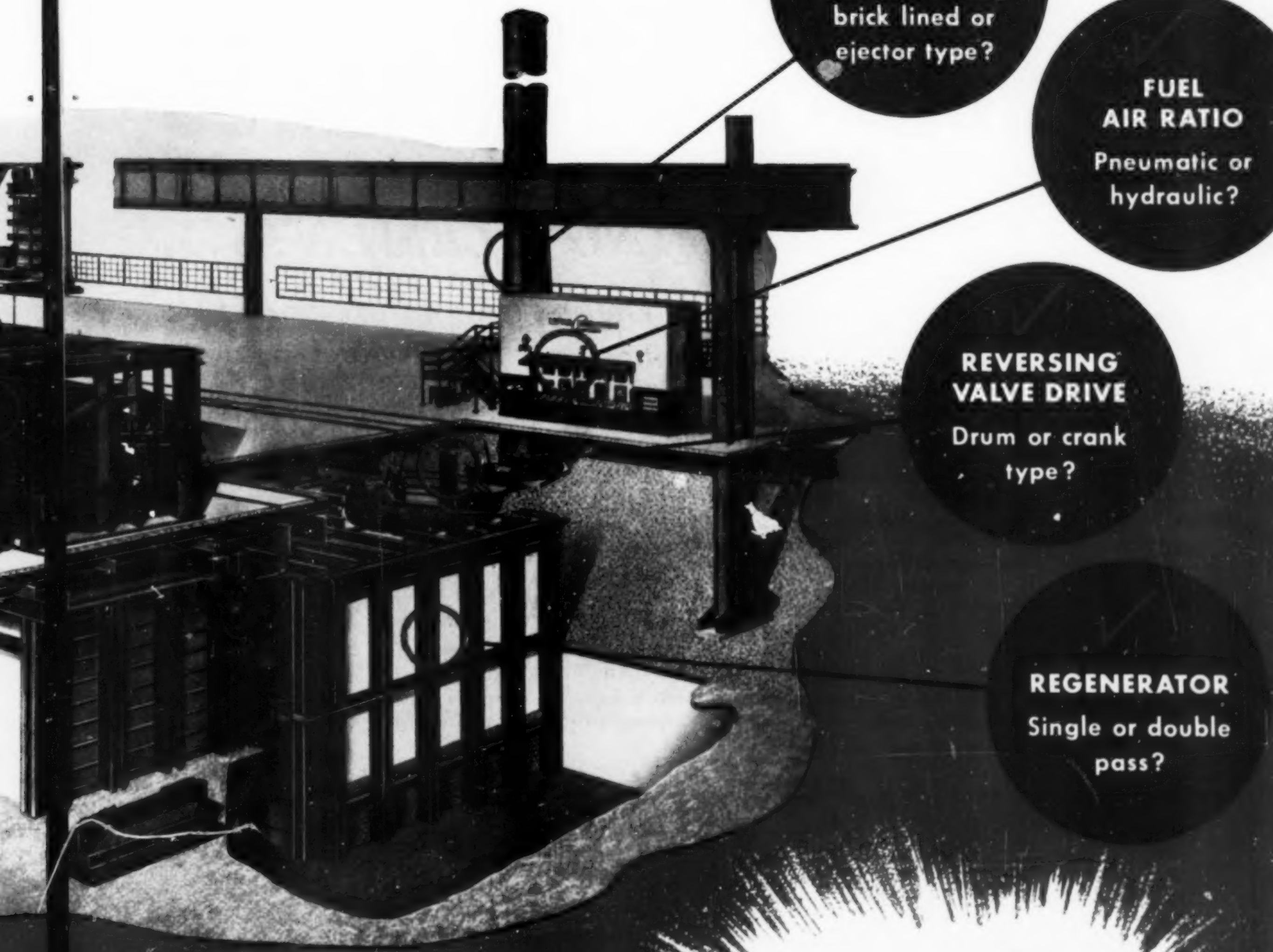
And, again let me repeat – Happy New Year to all!

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS


OPEN HEARTH OPERATORS:
Have you asked yourself
DOOR DRIVES
Fluid Clutches to reduce cable wear?
PORT ENDS
Suspended basic or double downtake silica?
FURNACE PRESSURE CONTROL
Hydraulic, pneumatic or electronic?
FURNACE TEMPERATURE CONTROL
Roof or backwall block?
LOFTUS CAN HELP YOU!
The answers to these questions rest in the cumulative experience of Loftus engineers. This know-how covers open hearths of every size and type, tailored for specific needs in many countries
FROM FIRST HEAT TO HEAT TREAT
Loftus
BUILDS 'EM BETTER
Loftus Designs and Builds Open Hearth Furnaces, Soaking Pits, Continuous Heating Furnaces, All Types of Heat Treating Furnaces, and 60-Cycle Induction Heating Furnaces.

these questions?



throughout the world. Each furnace, though individually designed and built to precise specifications, provides a flexibility in operation which insures the type of performance every steel maker demands.

SEND TODAY for this new, instructive brochure "Open Hearths by Loftus"; an illustrated description of modern open hearth design and construction.

Loftus ENGINEERING CORPORATION

Designers and Builders of Industrial Furnaces

610 Smithfield Street, Pittsburgh 22, Pennsylvania

NEW "HOT RODS" FOR ELECTRIC FURNACES

*CRYSTOLON*HEATING ELEMENTS...*

Another Norton ℞ Refractory...engineered and prescribed for longer service and lower costs

Now you can get longer-lasting heating elements for your electric furnaces!

During five years of laboratory and field testing, the new Norton heating elements have proved their ability to deliver as much as two to three times longer service life. They're the latest Norton ℞ — an expertly engineered refractory prescription — for electric furnace users who want to reduce operating and maintenance costs.

Here is the information in brief—

1. These rods are interchangeable with your present rods of comparable dimensions. No equipment changes are necessary.

2. These elements are silicon carbide crystals self-bonded at elevated temperature levels into round rods of various dimensions.

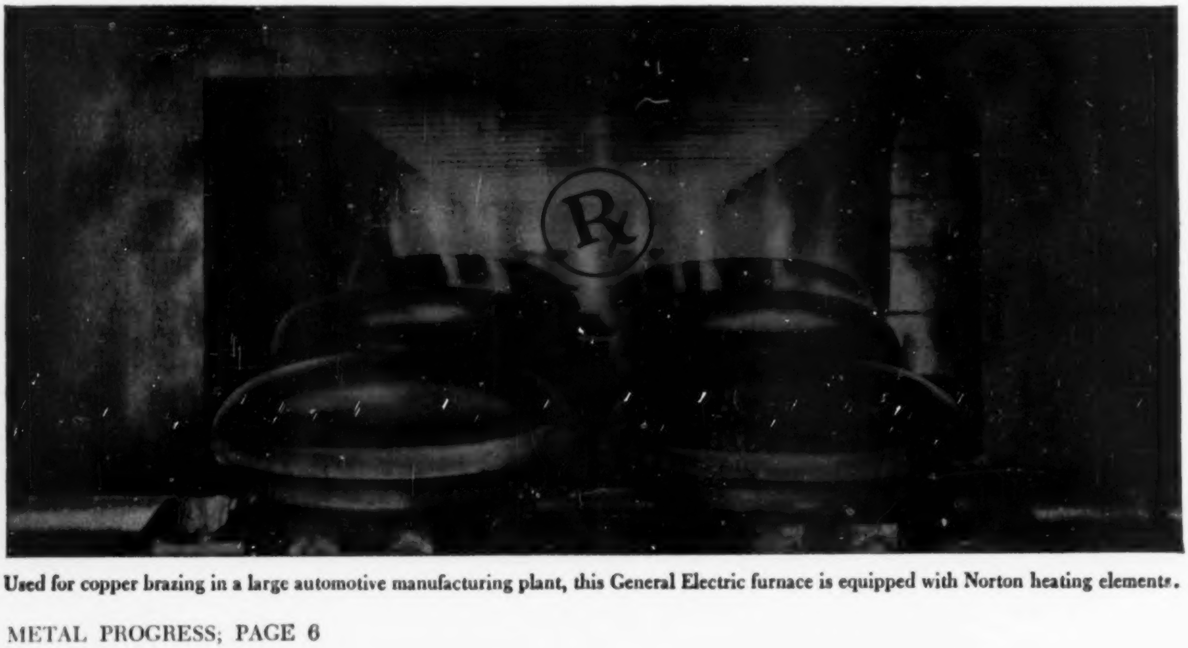
3. Each integral rod has a hot zone (the center) and cold ends.

4. Tips are sprayed with aluminum to provide a low-resistance contact for terminal straps.

5. Metal-impregnated ends result in a very low resistance — consequently little loss in power.

6. Elements are normally serviceable until a resistance of approximately four times the original value is reached.

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries



Used for copper brazing in a large automotive manufacturing plant, this General Electric furnace is equipped with Norton heating elements.

Pre-testing predicts performance

All elements are given a thorough final operating test. Any one size is always tested at the same voltage and the current drawn at this voltage is a measure of the resistance of the elements. To make matching elements easy, the test voltage is written on the left end of the element and the test current at the right end. These markings also appear on the container, which is specially designed to prevent rod breakage in shipment.

Norton makes the elements only

It does not make or design furnaces. Elements are now available in standard sizes up to and including 1¼" diameter. 1½" and 1¾" diameters will be available also in a few months. To be sure of the advantages and savings of CRYSTOLON heating elements, specify them through your furnace builder.

New sales engineering manual

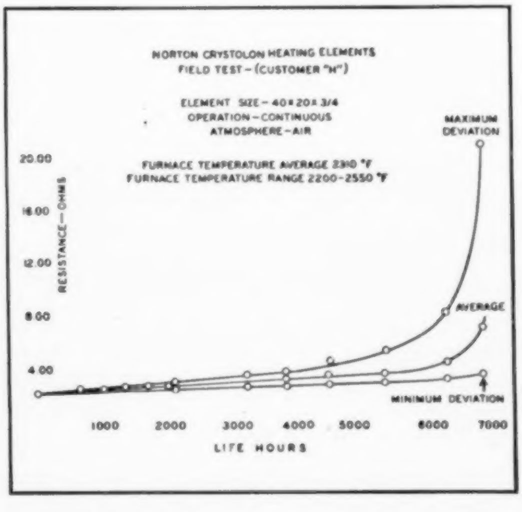
on Norton CRYSTOLON heating elements is now ready. It gives complete technical data, detailed characteristics and information on service life, power supplies, mounting methods, operation, etc. Write today, NORTON COMPANY, 320 New Bond Street, Worcester 6, Massachusetts.

NORTON

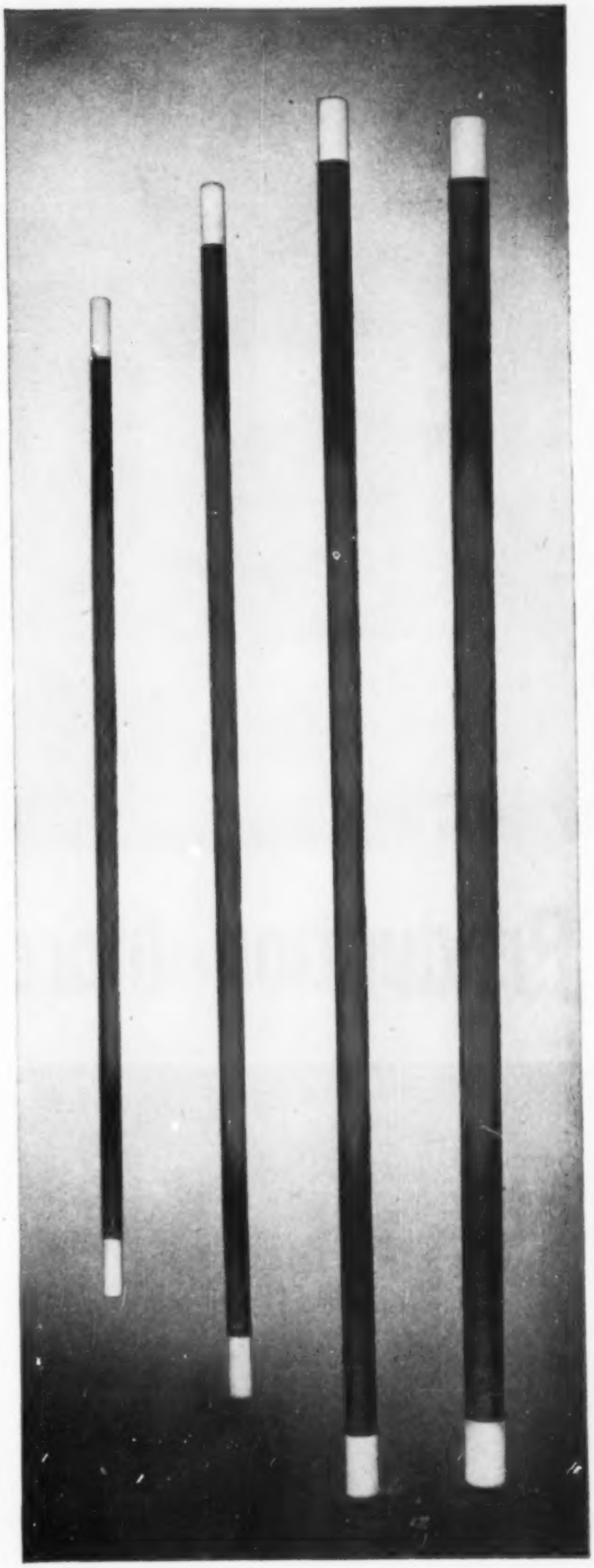
REFRACTORIES

Engineered . . . ℞ . . . Prescribed

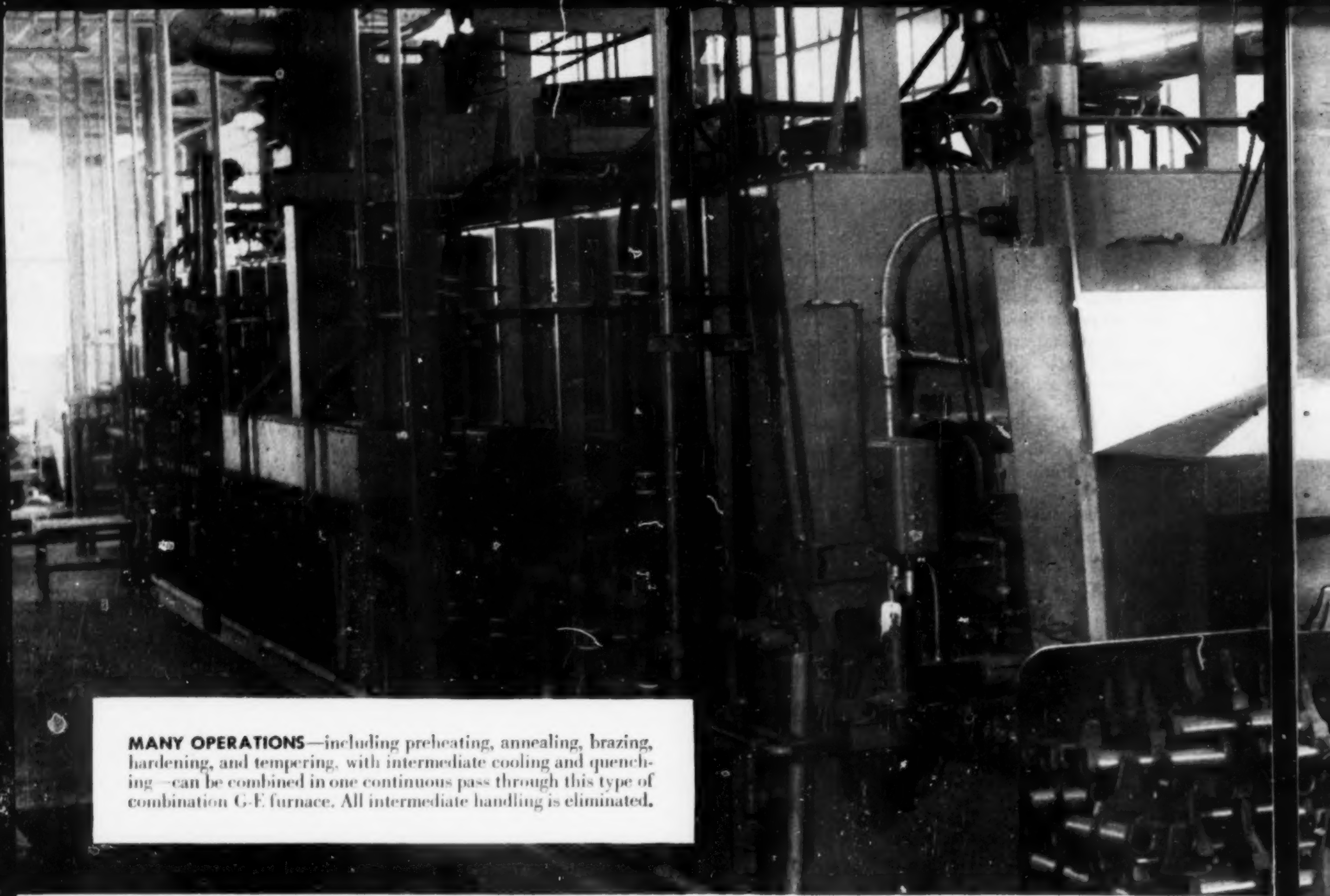
Making better products . . . to make other products better



Norton CRYSTOLON heating element field test. Element size — 40 x 20 x ¾". Continuous operation in air. In this test furnace temperature averaged 2310°F. Temperature range 2200°F — 2550°F.

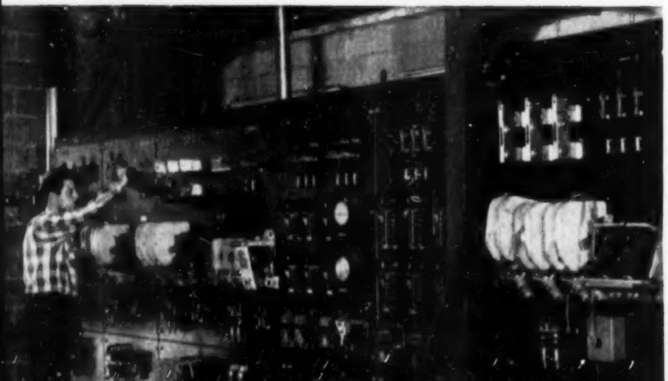


Representative sizes of Norton heating elements. Note aluminum-sprayed tips for contact straps.

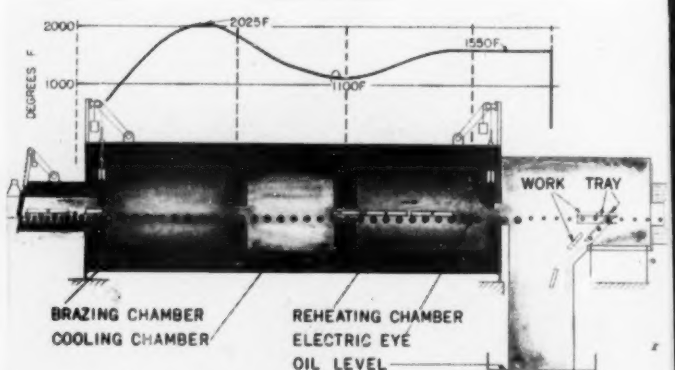


MANY OPERATIONS—including preheating, annealing, brazing, hardening, and tempering, with intermediate cooling and quenching—can be combined in one continuous pass through this type of combination G-E furnace. All intermediate handling is eliminated.

Production Increased Five Times



AUTOMATIC CONTROL AND TIMING of the complete heating cycle is provided by this G-E control panel. After heating pattern is set, panel supervision is not necessary, and uniform, high-quality heat treatment of parts is assured.



LONGITUDINAL SECTION VIEW of G-E roller-hearth furnace shows how assemblies pass through furnace during heat treatment. Straight-line heat treating like this simplifies furnace operation, and provides fast production and low handling costs.

Install a WELDCO Mechanical Tube Pickler As Youngstown Sheet & Tube did at *Indiana Harbor*

THE WELDCO Tube Pickler combines the advantages of extra mechanical agitation and fast chemical action. Uniform descaling is accomplished by alternately raising and lowering the load on spreaders. This rolling, tumbling, spreading action speeds up descaling; then the tubes are tilted, and the liquid carries away all loose scale, **completely** flushing out each tube. This fast inside flushing action cuts pickling time to a minimum . . . increases efficiency. With this in mind, and to insure adequate capacity for their new pipe mill, The Youngstown Sheet & Tube Co. ordered WELDCO Mechanical Tube Picklers.

Four 10-ton Picklers were installed in their new Indiana Harbor pipe mill, making it one of the largest pipe pickling installations in the country. The WELDCO Units in this plant handle pipe from 10' to 23'6" long, provide fast, efficient flushing action, with better finish, uniform pickling and descaling, and big savings in manpower, maintenance and steam consumption.

It will pay you to get all the details on WELDCO's complete line of Mechanical Picklers—available for Bars, Tubing, Coils and Sheets. Contact us for complete information, and for engineering service on your entire pickling line.

THE YOUNGSTOWN WELDING & ENGINEERING COMPANY
3719 OAKWOOD AVENUE · · YOUNGSTOWN 9, OHIO

How Physical Testing Helps Metals Engineers

By FREDERIC C. WEICKER
Vice President
Riehle Testing Machines Division
American Machine and Metals, Inc.
East Moline, Illinois

By applying the principle that one test is worth a thousand expert opinions, metals engineers can avoid the usual headaches that result from material failures. Physical testing also offers a wide area of money-saving possibilities which metals engineers can bring to the attention of top management. These possibilities become realities when physical testing is used to avoid processing of substandard materials. Three recognized stages for physical testing are:

1. **Incoming Materials** — Quality and uniformity of incoming raw materials and parts can quickly and easily be checked by accurate testing. Materials not up to standard can be rejected before flaws show up in machining and assembly. (See Fig. 1.)

2. **Sub-Assemblies** — Regular testing of sub-assemblies indicates the quality of welds, riveted joints or other operations. Faulty operations can be detected and remedied before a large number of substandard parts are produced.

3. **Finished Products** — Sample testing of finished products assures conformance to established company standards. Investigators in the field of finished product testing report customer complaints reduced and returned products minimized. (See Fig. 2.)

In selecting a testing machine to meet these requirements, the buyer is naturally concerned with the machine's ability to perform a wide variety of tests on a wide range of specimens. Pendomatic Universal Testing Machines, built by the Riehle Testing Machines Division of American Machine and Metals, Inc., rate high in this respect. Every Riehle Pendomatic Universal has five standard scale ranges, making it the equivalent of five testing machines in one. The same machine can be used to test specimens with relatively low rupture points and also high yield point specimens. Bulletins giving specifications of these machines may be secured from Riehle Testing Machines Division, Dept. MP-154, East Moline, Illinois. This literature will be found helpful by those metals engineers interested in achieving maximum benefits from physical testing.

Fig. 1 — Testing bending stress in bar stock.

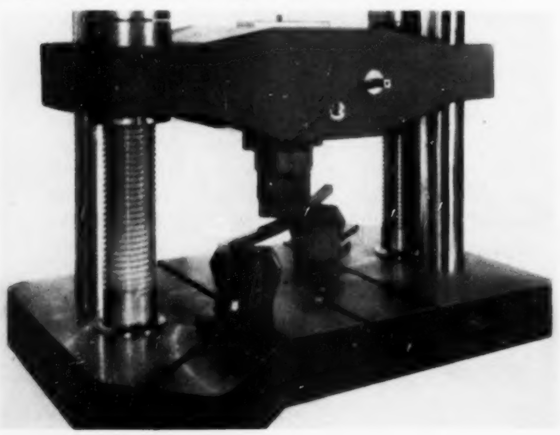
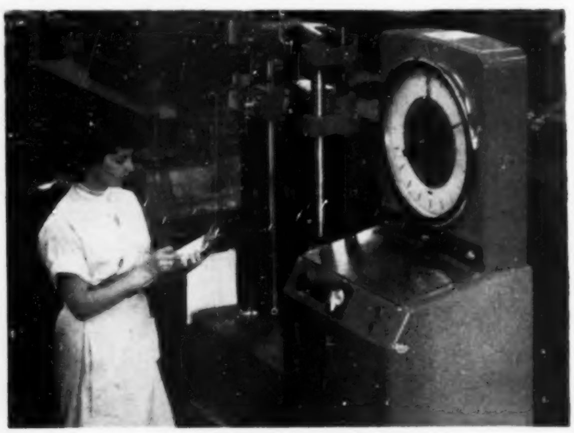


Fig. 2 — Checking tensile strength of a finished part.



engineering digest OF NEW PRODUCTS

Ultrasonic Probe

A new series of ½-in. diameter crystal transducers, or probes, for ultrasonic thickness gaging has been announced by Branson Instruments, Inc. Their efficiency and small diameter make possible precise thickness measurements on metal of sharply-tapering section, compound curvatures, and other unusual conformations previously impossible to measure

accurately. These type B transducers employ both quartz and barium-titanate ceramic as active elements, and have a sensitivity approximately equal to that of the conventional 1⅜-in.-diameter all-quartz probes. Due to their small contact area and high energy output, these new probes can be used on such difficult objects as knuckle bends, pipe elbows, and areas that are deeply grooved or excessively corroded.

For further information circle No. 1 on literature request card on p. 32-B.

Stretch Forming

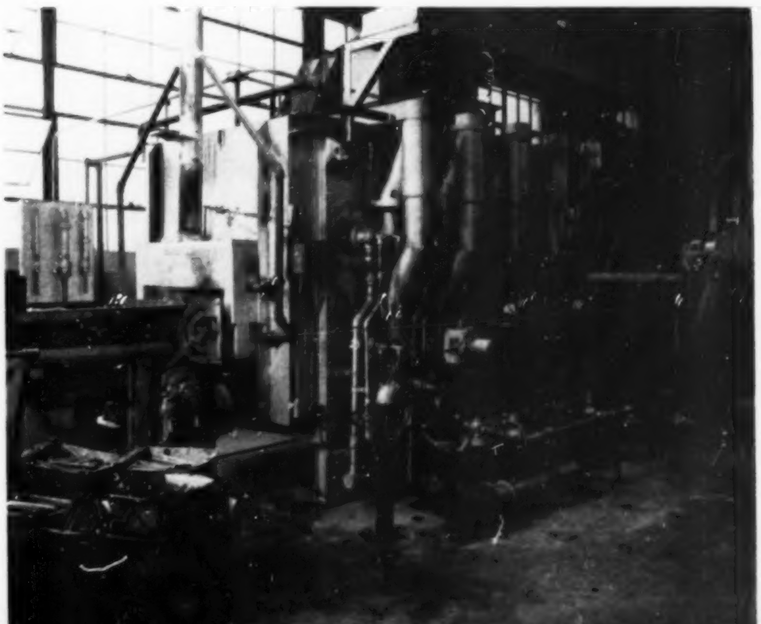
The R. A. Lalli Co. has developed a new method of stretch forming magnesium, employing thermostatically controlled heat. Initial deliveries of skins processed on this simplified stretch forming equipment have been to the aircraft industries on components such as outside skins, fairings, panels and other fuselage skins up to ⅛ in. The stretch forming machine is also being successfully used in stretch forming of aluminum. The Lalli method eliminates all hammering once the die is formed and does away with expensive stretch presses. Inexperienced labor can operate the machines and there is little maintenance. The equipment is small in size depending on the material to be formed. A major advantage is the low cost of dies. Dies are of shell type made of sheet steel from 0.074 to 0.125 in. thick, and cost less than half of the conventional stretch press dies. As illustrated (right), a group of machines can be installed in line so that one operator can handle several at one time. These machines are forming door skins. One operator produces 20 to 30 pieces a day on each die as compared with two or three with ordinary hammering methods. The manufacturer reports that doors and panels are being made to 0.040 in. thickness stretched over dies

Shaker Hearth Furnace

Small, light weight parts can be continuously hardened in a radiant tube, gas-fired shaker hearth furnace available from the Westinghouse Electric Corp. The furnace has a maximum operating temperature of 1700° F. and is designed for heat treating medium-carbon, high-carbon and alloy steels without scale or decarburization in an endothermic gas atmosphere. In operation, work is loaded on the hearth at the front of the furnace and the reciprocal motion of the shaker charger conveys the parts through the heating chamber until they fall off the discharge end of the hearth into the quenching fluid. The parts are then automatically conveyed from the quench tank on a mesh belt and discharged into tote baskets. The shaker mechanism is mounted on a separate stand so that the furnace receives no shock from the oscillation of the hearth.

The estimated production for this furnace at 1600° F. operating temperature, is 400 to 600 lb. per hr. The speed of the work through the furnace is adjusted by varying the operating ratio of the speed reducer which, in turn, varies the frequency of oscillation of the hearth. Typical applications include the hardening of pocket knife blades, small flat springs, screws, bolts and other small hardware. Parts which are round or which will roll en masse are not suitably conveyed by the shaker hearth.

For further information circle No. 2 on literature request card on p. 32-B.



0.074 in. thick with the skins retaining structural strength. There is no limitation to the size of the sheet, as machines can be made to any size.

For further information circle No. 3 on literature request card on p. 32-B.

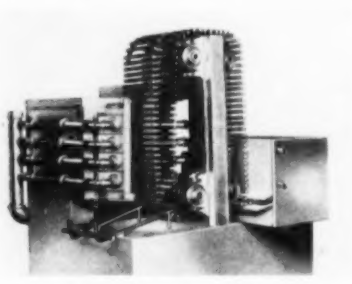
Hardness Tester

New pocket-size hardness testers—the smallest ever made which operate on the rebound principle—combine low cost and simplicity of use with consistent accuracy. The testers, known as Sklerografs and distributed by Kurt Orban Co., Inc., are specifically designed for on-the-spot testing. Objects weighing four pounds or more require no special provision for testing. Smaller objects, such as small machine parts, tools and sheets, should be placed on a steel block. Two models are available: Model M weighs only 5¼ oz., including container, which is 6½ in. long and ¾ in. in diameter. A somewhat larger type, Model D, weighs 9 oz. and is designed to withstand the rougher usage likely to be encountered in shop practice.

For further information circle No. 4 on literature request card on p. 32-B.

End-Heating Furnace

The new Gas Appliance Service end-heating unit is said to bring 4 in. lengths of ½-in. rod to 1900° F., in 50 sec., with an hourly production of 900 rods on the model illustrated. Rod of ¾ in. diameter reaches the same temperature in 75 sec. with hourly production of 600 rods. Designed with conveyor and automatic hopper feed, it handles stock sizes of rod from ¼ to 1½ in. diameter, in lengths of section heated up to 4 in., and over-all length of 6 to 24 in.



For further information circle No. 5 on literature request card on p. 32-B.

Zirconium Oxide

The Zirconium Corp. of America has been formed to manufacture various zirconium compounds, especially zirconium oxide. The new patented process to be used was developed by Sylvester & Co., under the direction of Dr. Robert A. Schoenlaub. A pilot plant was successfully run for over a year producing stabilized zirconium oxide. Present plans call for full-scale production early this year.

For further information circle No. 6 on literature request card on p. 32-B.

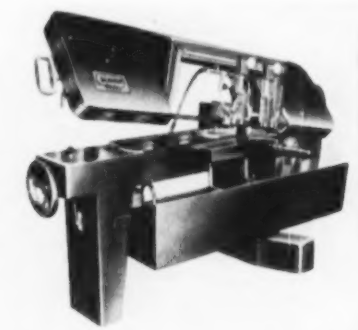
Laboratory Stirrer

Only 4¼ in. high, a new magnetic stirrer from Fisher Scientific Co. is designed as an answer to the space problem found in many laboratory bench assemblies. The Flexa-Mix has no arms to get in the way, no loose holders to flop around. Its low height means that it can be set under many more sample set-ups; and with less danger of toppling. This plate makes possible a wide variety of positions and tilts. A small, protected alnico magnetic bar placed inside the container to be stirred revolves at the same speed as the rotating magnetic field produced by the stirrer motor. Any glass, plastic, porcelain or nonmagnetic metal container can be used. The sample container can be open or completely closed—even sealed tight under vacuum or pressure—and the contents are still mixed efficiently at rheostat-controlled speeds up to 1650 rpm.

For further information circle No. 7 on literature request card on p. 32-B.

Metal Cutting Band Saw

A new horizontal metal cutting band saw has been announced by the Machine Tool Div., Kalamazoo Tank & Silo Co. The new model cuts 8-in. round stock, 16-in. flat stock, 8-in. pipe and a variety of shapes, including very thin sections. Saw frame



descent through the sawing operation is correctly maintained by a hydraulic mechanism. Cutting action of the blade is easily visible to the operator.

For further information circle No. 8 on literature request card on p. 32-B.

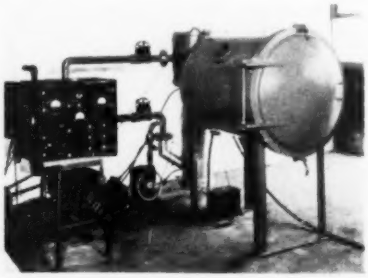
Nonmagnetic Stainless

A new iron-base alloy, developed as a substitute for stainless steel in the reinforcing braid of Signal Corps communications cable, has been announced by Battelle Memorial Institute. The new alloy should be useful in other applications requiring a material of moderate corrosion resistance, good workability and not easily magnetized. The alloy contains 0.08 to 0.15% carbon, 9.0 to 11.0% chromium, 14.5 to 18.5% manganese, 0.3 to 1.3% silicon, 1.8 to 2.2% copper and 0.08 to 0.15% nitrogen, balance iron.

For further information circle No. 9 on literature request card on p. 32-B.

High Vacuum Plating

The High Vacuum Equipment Corp. has developed a new 30-in. vacuum metallizing unit for coating various die-cast articles which are being electroplated today. With this process, an initial coating of lacquer is applied, a very thin film of evaporated aluminum is added, and a final coating of



clear lacquer gives durability to the mirror-like aluminum finish. This top coat of lacquer can then be dipped in a water-soluble transparent dye with a resulting brilliant gold, bronze, brass or silver metallic effect.

For further information circle No. 10 on literature request card on p. 32-B.

Burner

Ra-Diant Products Co. has announced a new pulsation-inspirator burner for heat treating, annealing and slow cooling furnaces. Constant

agitation of the atmosphere eliminates layering of air and gas. Another special feature is the catalyst liner. The burner consumes natural gas at 1 to 30 lb. pressure.

For further information circle No. 11 on literature request card on p. 32-B.

Continuous Furnace

Salem-Brosius, Inc., recently completed construction of a 64-ft.-long, oil-fired, continuous roller hearth furnace for the Winchester Repeating Arms Div. of Olin Industries, Inc. The furnace is designed to heat 24,000 lb. of brass slabs per hr. from room temperature to 1500° F. The slabs are 4½ in. thick by 28 in. wide and range in length from 5 to 36 ft.

For further information circle No. 12 on literature request card on p. 32-B.

Shell Molding

An advanced line of machinery for shell molding has been placed on the market by the Beardsley & Piper Div. of Pettibone Mulliken Corp. This new

Q **What can we do to step up production on our grinders and produce better work?**

Q **What will give us *fewer rejects* on our castings?**

Q **We need a drawing lubricant that will help speed up bar drawing and produce the desired surface finish.**

Q **Can we get 15% more machining speed, with enough cooling?**

Q **How can we prevent rust on these machined surfaces?**

. . . and answered with solutions!

Every supplier of metal processing products receives inquiries from men who are looking for help.

But not many have so diversified a line, for Houghton touches on nearly every phase of a metalworking plant's operations!

Houghton receives and handles hundreds of puzzlers every month, covering a wide range of processes . . . heat treating, drawing, rust prevention, lubrication, surface conditioning of metals, hydraulic packings and fluids, foundry casting, etc. . . . applications on which we've accumulated "know-how" over the years.

If such operations are giving you trouble, the Houghton Man may well have the answers you need—or can get them for you with the help of our research staff "back home".

Ask him next time he calls at your plant. Or write directly to E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa., for practical answers to your questions.

NEED MONEY-SAVING PRODUCTION IDEAS?

Try Houghton on these:

LUBRICANTS

For gears, spindles, hydraulics, molds, high temperatures and general plant use.

METALWORKING PRODUCTS

Cutting Oils and Bases • Drawing Compounds • Metal Cleaners • Rust Preventives • Foundry Core Binders • Salt Bath Materials • Quenching Oils • Surface Conditioners

HYDRAULIC PACKINGS

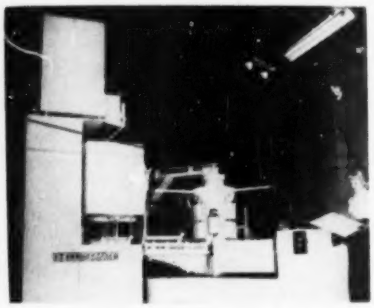
and Leather Belting

E. F. HOUGHTON & CO.

PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service . . .

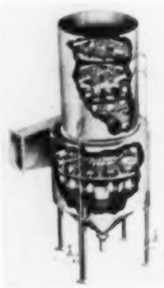
line of automatic and semi-automatic equipment has been engineered and developed in cooperation with the Winter Engineering Co. The accompanying illustration shows the multiple-station Shell-Formatic unit, which accommodates three different patterns and offers precise, fully automatic control of all operations.



For further information circle No. 13 on literature request card on p. 32-B.

Dust Control

A completely new system for controlling stack dust has been produced by Johnson-March Corp., with an unusually wide range of applications. Combining six different principles of dust precipitation, the system is capable of removing extremely large volumes of dust from the stack gas. The unit is especially adapted to the control of dust from rotary dryers, cyclones, kilns, roasters and from the stacks of foundries and steel producing plants. This "LP" scrubber is built in various sizes for capacities ranging from 1500 to 48,000 cfm. The units range in physical size from about 15 to 33 ft. high. All of the dust removed from the air is reduced to a watery sludge which can be discharged into a tank or pond for easy removal of the solids. A recirculation system can be used where water supply is a problem. For best results, the system requires approximately 2 gal. of water per min. at 40 to 50 psi. for each 1000 cu. ft. of gas per min.



For further information circle No. 14 on literature request card on p. 32-B.

Hardenable Stainless Alloys in Cast Form

The Donegal Mfg. Co. has announced production of DC-50 castings under a license agreement with the Armco Steel Corp. DC-50 is essentially the same as the Armco 17-4 PH hardenable stainless alloy which previously has been produced in wrought form only. The hardness of the alloy is secured by a precipitation hardening treatment. In the hardened condition the new alloy has a minimum tensile strength of 180,000 psi. and minimum yield strength of 165,000 psi. The alloy contains 0.05% carbon, 16.5% chromium, 4% nickel, and 4% copper. Corrosion resistance is better than that of the 12 to 14% chromium alloy which is usually employed to obtain similar mechanical properties, and is very close to the corrosion resistance of the common 18-8 stainless alloys.

For further information circle No. 15 on literature request card on p. 32-B.

Crucible

Quick pouring without spillage is the claim for this unique coffee pot lip crucible, manufactured by Electro Refractories & Abrasives Corp. The design was conceived jointly by

Electro and Bohn Aluminum & Brass Corp. This spout is believed the first to be successfully joined to a carbon-bonded silicon carbide body below the metal line. Capacity of the pot is 125 lb. of aluminum.

For further information circle No. 16 on literature request card on p. 32-B.

Portable Hot Plate

An inexpensive portable hot plate by Lindberg has sheathed nichrome heating elements cast into the aluminum top plate insuring quicker heating (750° F. in 35 min.), good uniformity, and exceptionally long element life. "Stepless" control permits precise control of temperature. Terminals are protected from spillage and short circuits. The equipment has a diameter, top plate and base, of 8 in., power rating of 660 watts, power service of 115 volts, 50/60 cycle.

For further information circle No. 17 on literature request card on p. 32-B.

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

40. Abrasion Tester
Bulletins on durable precision instrument for testing resistance of surfaces to abrasion. *Taber Instrument*

41. Abrasive Cutting
20-page booklet 6, "Metallic Cutting Off With Abrasive Wheels". *Abrasives Div., Carborundum Co.*

42. Allowable Stresses
Data Card 154 gives max. allowable stress values for 22 types of steel tubing. Formulas for calculation of max. working pressures. *Babcock & Wilcox*

43. Alloy Selection
Chart to select alloy for given corrosive problem. 350 corrosives included. *Cooper Alloy Foundry*

44. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

45. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

46. Aluminum Alloys
36-page book on analysis of aluminum, brass, bronze alloy specifications. *Sonken-Galamba Corp.*

47. Aluminum Extrusions
28-page book on extruded aluminum products. Design, tolerances, applications. *Revere*

48. Aluminum Extrusions
Data on services in the field of aluminum extrusions. *Himmel Bros. Co.*

49. Aluminum Heat Treating
Bulletin on furnaces for aging, annealing, heat treating and forging aluminum. *Morrison Eng'g Corp.*

50. Aluminum Heat Treating
8-page Bulletin 5912 on solution heat treating, annealing, stabilizing and aging of aluminum. *General Electric*

51. Ammonia Dissociators
Bulletin on dissociating process gives advantages of ammonia as controlled atmosphere. *Sargeant & Wilbur*

52. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

53. Annealing
Experience at Johns-Manville with atmosphere furnace for annealing gaskets and miscellaneous parts. *Sunbeam*

54. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, production data. *Drever*

55. Anodizing
Data on aluminum racks with copper hooks for anodizing. *National Rack*

56. Arc Welding
44-page catalog describes over 20 models of arc-welding machines, with sections on accessories and electrodes. *Air Reduction*

57. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

58. Atmosphere Furnace
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

59. Atmospheres
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

60. Atom Models
12-page booklet on construction of scale models of atomic crystal structures. *Fisher Scientific*

61. Barrel Finishing
Folder on design and advantages of barrel finishing machine. *Minnesota Mining & Mfg.*

62. Barrel Finishing
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chemical*

63. Bearings
Service data on aluminum-on-steel bearings. Comparison with babbitt and bronze bearings. *Johnson Bronze Co.*

64. Belt Polishing
Bulletin gives case histories of back-stand-belt polishing. *Coated Abrasives, Div., Armour & Co.*

65. Bending and Cutting
Folder describes hand and air-operated bender-cutter and its applications. *J. A. Richards*

66. Beryllium Copper
16-page booklet on applications and properties of beryllium copper. *Beryllium Corp.*

67. Black Oxide Coatings
Data on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

68. Black Oxide Finish
Folder on penetrating black finish for ferrous metal. *Puritan Mfg.*

69. Blackening Compounds
Bulletin on blackening compounds for ferrous alloys to AMS Spec 2485. *Swift Industrial Chemical*

70. Brass
80-page book on properties and uses of brass forgings, sand castings, rods and machinings. *Mueller Brass*

71. Brass Foundry
Article discusses sand in the brass foundry. *Lavin*

72. Brass Wire
10-page booklet gives properties, finishes, chemistry of extruded cold heading brass and copper wire. *Chase*

73. Brazed Tubing
12-page data book on brazed tubing made from copper-coated steel. *Bundy*

74. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

75. Brazing and Annealing
Bulletin on high speed heating equipment for brazing, annealing, flame hardening, selective heating, heating for forming. *Gas Appliance Service*

76. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

77. Bronze
12-page bulletin on properties and uses of continuous cast bronze rod and tube. *American Smelting & Refining*

78. Burners
20-page catalog of oil, gas and combination burners. *Petro*

79. Burners
Bulletin on combination gas and oil burner. *Ra-Diant Products*

39. Atmosphere Control

Things will go wrong with a protective atmosphere. This reprint bulletin tells how to cure such troubles. Sections include atmosphere impuri-

ties, tests for leaks in furnaces, control of decarburization, how atmospheres affect resistor alloys, thermocouples and refractories, and a check sheet for troubles and cures. *General Electric*

80. Carbide Segregation
Effect of carbide segregation in tool steel. *Latrobe Steel*

81. Carbide Tools
92-page catalog of standard and various special carbide tipped and solid carbide tools. *Super Tool Co.*

82. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical, process fields. *National Carbon*

83. Carbon, Sulphur Analysis
Folder on induction furnaces for carbon and sulphur analysis. *Laboratory Equipment*

84. Carbon Control
Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup*

85. Carbon Steel Castings
Data folders on four types of carbon

Spectacular Beginning
of a SPECTACULAR STEEL

Special Steels for Armament
for Industry
for the Home

An electric furnace puts on a terrific show when we drop in a charge (as above) but it's only indicative of the great performance the steel will give later in service. For these are the high-alloy steels, stars of the metal world . . . the steels that give you so much more than they cost in resisting corrosion, heat, wear or great stress—or in providing special electrical properties. ● They can help *you* cut costs, improve quality, or add sales appeal. Let's get together on it. ***Allegheny Ludlum Steel Corporation, Oliver Bldg., Pittsburgh 22, Pa.***

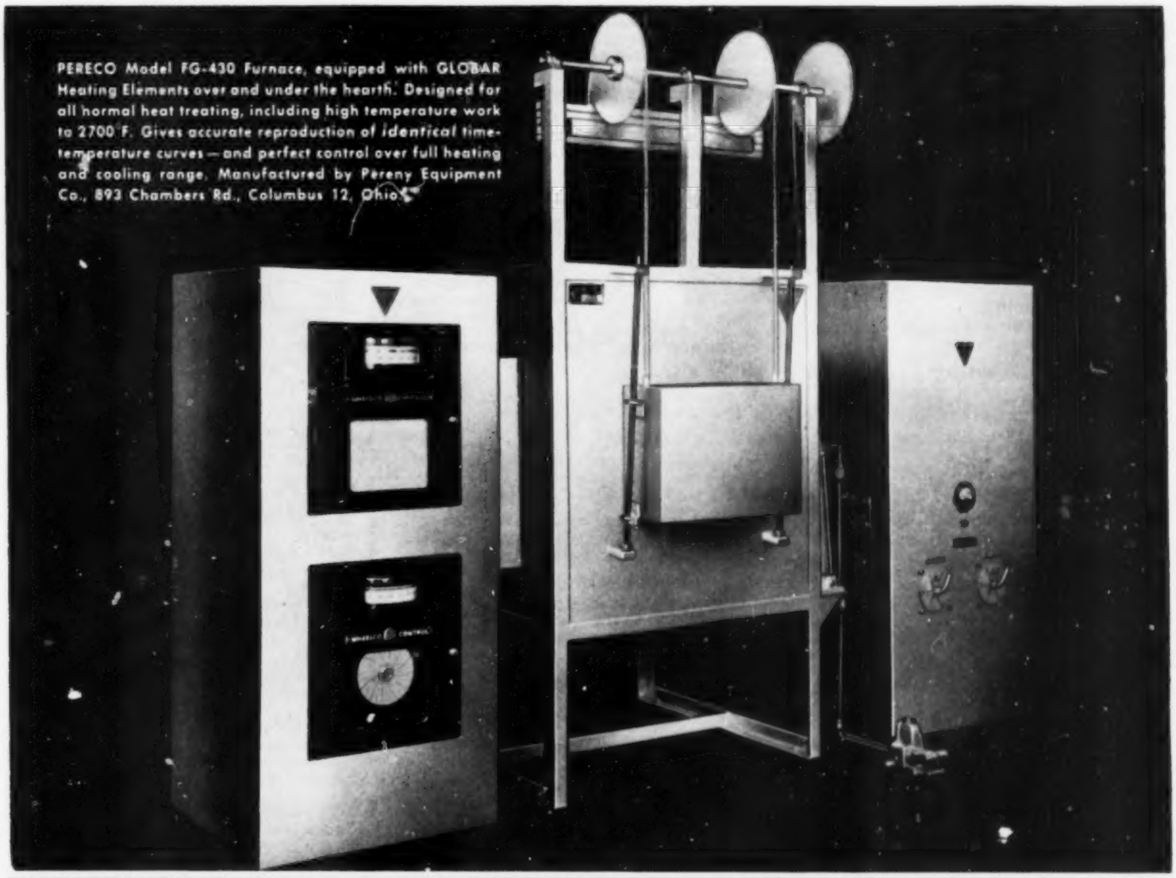
W/D 4145 B

PIONEERING on the Horizons of Steel

Allegheny Ludlum

A-L LEADING PRODUCER HIGH-ALLOY STEELS

Warehouse stocks of A-L Stainless carried by all Ryerson plants



PERENY selects GLOBAR® Heating Elements

...for this High Temperature Heat Treating Furnace

GLOBAR Silicon Carbide Heating Elements were chosen by Pereny for this modern, accurate heat treating furnace because they convert electrical energy into clean, safe, uniform, dependable heat.

Pereny is one of 40 leading furnace manufacturers who specify GLOBAR Heating Elements in many of their electric furnaces. GLOBAR's engineering staff works closely with these manufacturers to give *you* the most modern, efficient, and economical equipment for industrial heating processes—whether it be heat treating, brazing, annealing, forging or sintering.

Any problem you may have in the medium and high temperature range of industrial heating will be tackled vigorously by our engineers ...without obligation to you. The solutions they propose often result in much lower overall operating costs—even when electricity costs more than other fuels! Write to the GLOBAR Division, Dept. MP 87-42, The Carborundum Company, Niagara Falls, N. Y.

GLOBAR® Heating Elements

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87-42

steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

86. Carbonitriding
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

87. Carbonitriding
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

88. Carburizing
16-page bulletin SC-134 reviews gas carburizing techniques and possibilities. *Surface Combustion*

89. Carburizing
Bulletin on deep case liquid carburizing. *Park Chemical*

90. Case Hardening
Bulletin 159 describes standard rated batch furnaces for case hardening. *Surface Combustion*

91. Cast Iron
"Guide to the Selection of Engineering Cast Irons". *International Nickel*

92. Casting Specifications
Design values for five grades of heat resistant castings. *Ohio Steel Foundry*

93. Cemented Carbides
10-page bulletin on use of cemented carbides in wearproofing pulverizing equipment. *Carboloy Dept.*

94. Centrifugal Casting
Folder on advantages of centrifugally cast aluminum, copper and other nonferrous alloys. *HR Engineering Laboratories*

95. Chromate Coatings
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

96. Chromium Plating
"How to Chromium Plate 20 to 80% Faster" describes self-regulating high-speed bath. *United Chromium*

97. Clad Metals
24-page booklet on principles of bonding, characteristics of clad metals, methods of cladding, uses. *Superior Steel*

98. Clad Wire
Booklet on properties of nickel-clad copper wire for conductivity use at high temperature. *Sylvania Electric*

99. Cleaning
44-page booklet, "Some Good Things to Know About Metal Cleaning," discusses tank, barrel and machine cleaning, pickling, zinc phosphate coating, rust prevention and other processes. *Oakite*

100. Cleaning
20-page bulletin 214 gives performance on Rotoblast cleaning. *Pangborn*

101. Cleaning
6-page bulletin includes concentrations for various metal cleaning applications and a list of cleaners. *E. F. Houghton*

102. Cleaning Stainless
8-page booklet on care and cleaning of stainless steels. *Republic Steel*

103. Coated Abrasives
Bulletin on how to store coated abrasives. Effects of temperature and humidity. *Coated Abrasives Div., Armour & Co.*

104. Cold Finished Bars
Engineering bulletin, "New Economies in th Use of Steel Bars." *LaSalle Steel*

105. Cold Finished Steel
8-page bulletin on selection, use, relative cost of cold finished carbon steel bars. *Ryerson*

106. Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

107. Continuous Casting
Folder on use of graphite in continuous casting process. *International Graphite*

108. Controlled Atmospheres
Bulletin 753 on generator for atmospheres for hardening, brazing, sintering and annealing carbon steels. *Hevi Duty*

109. Copper Nickel Alloys
8-page bulletin on composition, properties and applications of series of 12 copper-nickel-base alloys available in cast form. *Waukesha Foundry*

110. Corrosion Resistance
New chart indicates resistance of seven classes of corrosion resistant cements to 297 of the most generally used corrosive chemicals. *Pennsylvania Salt*

111. Corrosion Resistant Alloy
Data sheet compares corrosion properties of Elgiloy and stainless steel. *Elgin National Watch Co.*

112. Corrosion Resistant Linings
Booklet on acid and alkali-proof cements, linings and coatings for pickling tanks, chemical equipment and other uses. *Electro Chemical Eng. & Mfg.*

113. Creep Testing
Data on operation and instrumentation of Arcweld lever arm creep testing machine. *Minneapolis-Honeywell*

114. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

115. Cut-Off Wheels
36-page revised manual on cut off machines and abrasive wheels. *Norton Co.*

116. Cutting Compounds
Data on cutting compounds for stainless and titanium. *Hangsterfer's Labs.*

117. Cutting Oil
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

118. Cutting Oil
Shop notebook gives important facts on right cutting fluid for any machining operation. *D. A. Stuart*

119. Cutting Oil Chart
Selection chart for seven classes of metal in nine machining operations. *Aldridge Industrial Oils*

120. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

121. Design of Dies
32-page bulletin on design of dies for upset forging. Also rules for upsetting and examples of forgings. *Ajax Mfg.*

122. Die Castings
Folder on possibilities and advantages of die castings. *Precision Casting Co.*

123. Electrical Steel
80-page book of engineering data on silicon steels for the electrical industry. *Republic Steel*

124. Electropolisher
Bulletin on theory and practice of electrolytic polishing of metallurgical samples. Description of electropolisher. *Buehler*

125. Fabrication
46-page book shows metal fabrication and production facilities, products and services. *R. C. Mahon*

126. Fasteners
80-pages of weights and dimensions of nuts, bolts, screws, washers, rivets. *Triplex Screw Co.*

127. Fatigue of Magnesium
18-page paper, "Plastic Flow and Work Hardening Phenomena in Magnesium Alloys During Fixed-Deflection Fatigue Tests". *Dow Chemical*

128. Finishing
52-page booklet on deburring and finishing equipment, and barrel finishing. *Almco*

129. Finishing Systems
Bulletin on cleaning and rust-proofing equipment, spray booths and drying ovens. *Peters-Dalton*

130. Flaw Detection
12-page bulletin on location of flaws by two dye-penetrant inspection methods. *Turco Products*

131. Flow Meters
24-page manual on application and installation of indicating flow meter. *Meriam Instrument*

132. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

133. Flux, Aluminum Melting
Data sheet on four fluxes for degassing and purifying aluminum alloys. *Atlantic Chemicals and Metals*

134. Forging Manipulators
Folder on manipulators for automotive, ordnance, aluminum and specialty forging. *Salem-Brosius*

135. Forming Dies
Data on roller dies for forming tubes and rolled shapes. *American Roller Die*

136. Forming Dies
Folder on styles of forming dies for stainless heads—in wide range of sizes and gages. *Carlson*

137. Forgings
20-page Catalog 51 on various types of forgings, their strength and related data. Tables, drawings. *Merrill Bros.*

138. Foundry Supplies
28-page catalog 1043C on oil and gas-burning equipment for cupola lighting, mold drying, ladle heating, core baking, furnace heating. *Hauck*

139. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

140. Furnace Construction
12-page bulletin on thin-wall construction for furnace enclosures. Engineering drawings. *Bigelow-Liptak*

141. Furnace Controls
Bulletin on instruments and controls for heat treating furnaces. *Hays Corp.*

142. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

143. Furnaces
High temperature furnaces for temperatures up to 2000°F are described in bulletin. *Carl-Mayer Corp.*

144. Furnaces
12-page brochure on car furnaces of special and conventional design. *Jet Combustion*

WHAT DOES FIRTH STERLING OFFER YOU?

(ANSWER NUMBER 4)

RESEARCH THAT ANTICIPATES TOMORROW'S NEEDS

Our objective is to help *you* solve the technical and metallurgical problems of an *atomic* age *before* they arise . . . not *after.* So, at Firth Sterling, constant emphasis is on full-scale research, development, and production in specialty steels, carbides, new metals, and new methods.

Out of this determination to be ahead, not just abreast of need, has come this amazing three year record of achievement in *your* interest:

- A method of heat tinting that makes *Color Metallography* practical for determining the exact structure-property relationship of carbide mixtures.*
- New metals of great present and future potential that include heavy metal, three grades of chromium carbide, titanium carbide, and high temperature alloys.
- Cermets—those amazing hybrids of ceramic and metal, possessing in *combination* the best characteristics of each, to overcome modern technological problems.
- Zirconium—in ingot, billet, bar, rod, strip, sheet, wire, and tubing form—soon to be available for industrial applications.
- A new chemical plant, employing the most advanced processes and equipment, producing ammonium paratungstate of the highest *purity* to improve the quality of our tungsten carbides.
- Method "X"—an electro-mechanical process for machining metals that are unmachinable by conventional means.

Yes, all these are the result of "accent on research" . . . the justification for our statement

Firth Sterling Stands for Metallurgical Achievement—Past, Present, Future

**Write for reprint of article from Oct. 19, 1953 issue of STEEL.*

1-4

A mule is a hybrid

So is a CERMET

A CERMET is what scientists the world over want—a hybrid material, like the mule, but possessing in combination all the best characteristics of several materials which by themselves cannot fill the demands of twentieth century technology.

In the forefront of the race for the jet-era hybrid is a CERMET. A mule of materials, CERMET results from mating a ceramic material with a metal. Thus, the name CERMET. Its physical characteristics are such that research men *everywhere* are striving for its perfection.

You see, man has reached a point where advancement in some directions is limited by the "survival" characteristics of existing materials. Jet propulsion, for example, may soon be stymied by the disintegration of available materials under high stress. Involved in this modern-day trial-by-fire are such technicalities as catastrophic oxidation, thermal shock failure, non-resistance to impact and "creep"—which is elongation under high temperature and stress.

Firth Sterling is now producing CERMETS for *many* applications!

But, mule-like, CERMETS have some stubborn little characteristics which must be "bred out" before the ultimate "wonder" hybrid emerges. We are sure it will emerge from blue-ribbon breeding . . . because Firth Sterling stands for metallurgical achievement . . . past, present and future.

R-201

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PRODUCTS OF FIRTH STERLING METALLURGY

High Speed Steels
Tool & Die Steels
Stainless Specialties
High Temperature Alloys

Sintered Tungsten Carbides
Firth Heavy Metal
Chromium Carbides
High Temperature Cermets

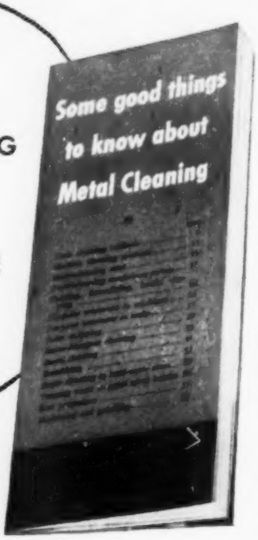
WHICH

METAL-CLEANING

JOBS

WOULD YOU LIKE

TO IMPROVE?



Listed below are some of the operations discussed in Oakite's 44-page handsomely illustrated booklet on Metal Cleaning. Please check the list. Then let us show you how Oakite methods can give you better production with greater economy.

Technical Service Representatives in Principal Cities of U. S. and Canada

SPECIALIZED INDUSTRIAL CLEANING
OAKITE
MATERIALS • METHODS • SERVICE

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Tell me about Oakite methods and materials for the following jobs:

- ☐ Tank cleaning
- ☐ Machine cleaning
- ☐ Electrocleaning
- ☐ Pickling, deoxidizing
- ☐ Pre-paint treatment
- ☐ Zinc phosphate coating
- ☐ Paint stripping
- ☐ Steam-detergent cleaning
- ☐ Barrel cleaning
- ☐ Burnishing
- ☐ Rust prevention
- ☐ ALSO send me a FREE copy of your booklet *"Some good things to know about Metal Cleaning"*.

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Company ______________________

Address ______________________

Dependable "ON-OFF" Controllers For Industry

The kind of control instrument which industry calls "on-off" or 2-position is not only the oldest form of automatic regulator, but is one which many manufacturers still use, instead of more advanced types, for simple requirements. Usually, the instrument merely closes the valve when temperature reaches the control point, and opens the valve again when temperature falls below point. The question of whether such on-off action is best for the given case can of course be settled by using the instrument with the best, most useful features. Here are some which L&N On-Off Controllers offer:

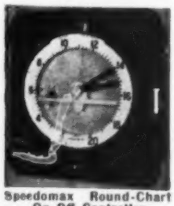
1. Instruments may be Recording Controllers with either strip-chart or round-chart, or Controllers with no charts at all.
2. Instruments can operate at high speed; are not affected by vibration or distance from process.
3. Controls are outstandingly dependable because they "balance" temperature against a standard.
4. Low maintenance assured by machine-like design and construction.
5. More than 1000 standard ranges, Specials are available.

Catalog free; please specify instrument. Write Dept. at Los Angeles 22, San Francisco 3, Seattle 1, or Philadelphia 44.

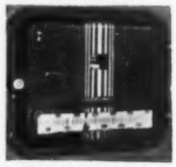
LEEDS NORTHRUP
instruments · automatic controls • furnaces

Jrl Ad ND4-33(5)

Speedomax (or Micromax) Strip-Chart Controller



Speedomax Round-Chart On-Off Controller



Micromax Model C

Electromax

REVCO SUB-ZERO CHESTS

Temperatures as low as

-95°

BELOW ZERO

For Shrink Fits

•

Seasoning Gauges and Precision Tools

•

For Tests

Completely equipped ready for operation. The 1.5 Cu. Ft. model as shown handles parts or assembled units up to 23'' long, 12½'' deep x 9'' high and the 6.5 Cu. Ft. model up to 47'' lengths, 16'' deep x 15'' high. Revco Sub-Zero Chests meet highest performance standards featuring temperatures of 95° and 85° below zero while running continuously in normal room temperatures. Other controlled low-temperatures readily attained.

REVCO RIVET COOLER for aircraft application is equipped with 90 rivet canisters in six convenient removable racks. Operates efficiently at temperatures as low as minus 35° F.

WRITE FOR DATA AND PRICES.

REVCO, INC...DEERFIELD, MICHIGAN

145. Furnaces
40-page book describes gas and electric furnaces and applications. Four basic types of atmospheres. Glossary of heat treating terms. *Westinghouse*

146. Furnaces
Folder describes complete set-up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

147. Furnaces
Bulletin 435 describes new furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

148. Furnaces, Heat Treating
Bulletin on furnaces for annealing, normalizing, hardening, tempering, forging. *Flinn & Dreffein Eng'g*

149. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

150. Furnaces, Heat Treating
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

151. Furnaces, Heat Treating
Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

152. Furnaces, Laboratory
26-page "Construction of Laboratory Furnaces" contains many diagrams, charts, tables, and information on how to construct furnaces. *Norton Co.*

153. Gamma Radiography
Data file on equipment and sources for cobalt 60 radiography in industry. *Technical Operations*

154. Gas Analysis
48-page catalog 81 on equipment and accessories for gas analysis. *Burrell*

155. Gear Hardening
Folder on application of induction heating to high-production hardening of gears. *Westinghouse*

156. Grainal Steel
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

157. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

158. Graphite Electrodes
164-page vest-pocket data book on graphite electrodes and electric-arc furnace practice. *International Graphite*

159. Graphitic Tool Steels
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

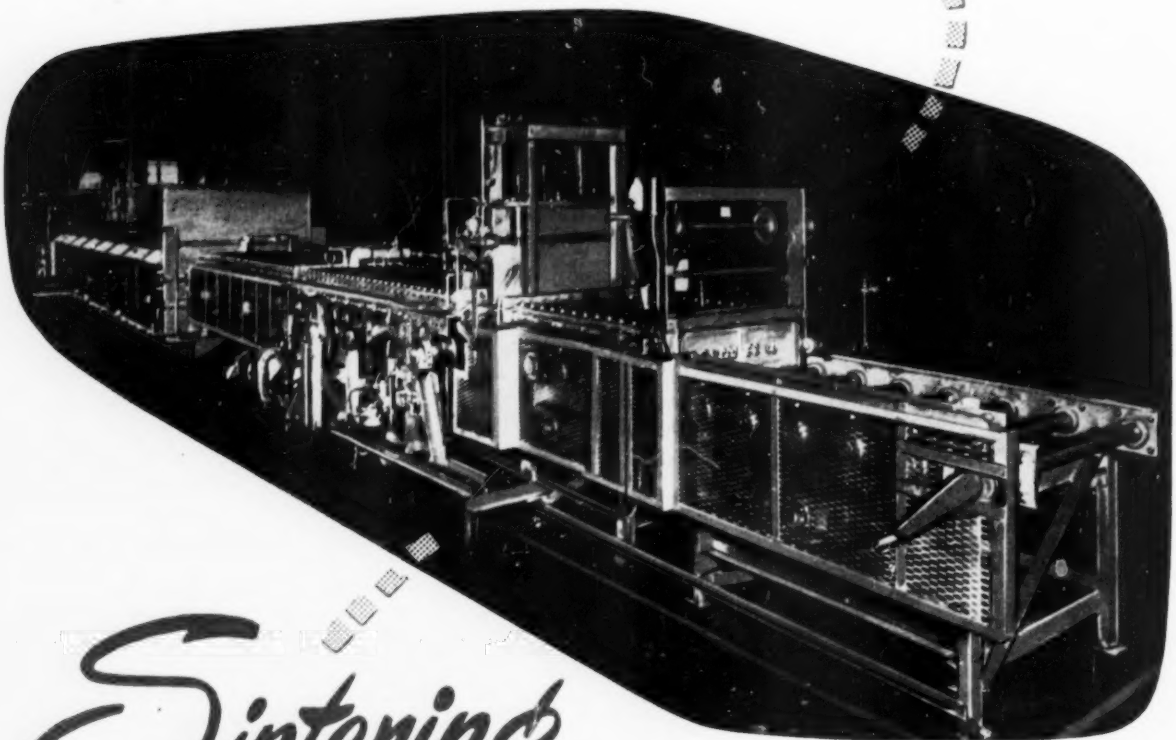
160. Handling Devices
Pamphlets on clamps for lifting and handling. Their application to various industries. *Merrill Bros.*

161. Hard Surfacing
40-page Hard-Facing Manual tells what metals can be hardfaced, how to select right hardfacing material, lists step-by-step procedures and industrial applications. *Haynes Stellite*

162. Hard Surfacing
12-page article on selection and evaluation of methods of hardfacing. *Air Reduction Sales*

163. Hardening Stainless
24-page "Story of Malcomizing" describes surface hardening of stainless steels. *Lindberg Steel Treating Co.*

DREVER



Discharge end of Continuous Sintering Furnace

Sintering

FURNACES

Experience, tested design and construction will serve your individual production needs for powdered metals and similar controlled atmosphere requirements . . . Batch type or continuous furnaces are available.

DREVER CO.

780 E. VENANGO ST., PHILADELPHIA 34, PA.

164. Hardening Stainless
64-page booklet on Super Scottsonizing process of hardening stainless steel. *C. U. Scott*

165. Hardness Numbers
Pocket-size table of Brinell hardness numbers incorporating other tabular information. *Steel City Testing*

166. Hardness Tester
4-page bulletin on Brinell hardness tester weighing 26 lb. for portable and stationary use. *Andrew King*

167. Hardness Tester
Circular on portable hardness tester in sizes for work 1 to 6 inches round and flat. *Ames Precision*

168. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

169. Heat Resisting Alloy
Pyrasteel bulletin describes chromium-nickel-silicon alloy for service economy in resisting oxidation and corrosion to 2000° F. *Chicago Steel Foundry*

170. Heat Treating
Catalog P-3 on furnaces for heat treatment of high speed steel. *Sentry*

171. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

172. Heat Treating
Loose leaf data sheets on heat treating oils, salts, carburizing compounds. *Park Chemical*

173. Heat Treating
72-page catalog on carburizing, cyaniding, brazing, austempering and annealing processes. *Ajax Electric*

174. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div., Allied Chemical & Dye*

175. Heat Treating Fixtures
24-page catalog B-8 on muffles, retorts, baskets, other fixtures for heat treating in gas or salt baths. *Rolock*

176. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

177. Heat Treating Guide
Chart guide constructed on slide rule principle for simplified hardening and drawing of tool steels. *Carpenter Steel*

178. Heat Treating Pots
Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

179. Heating Elements
24-page book on electric heating elements for use up to 2800° F. *Norton*

180. Heliarc Welding
Pocket-sized folder contains current ranges and sizes for electrodes with table on current and number of passes required to weld various metals. *Linde*

181. High-Alloy Castings
28-page "Ni-Cr Castings to Resist Heat and Corrosion". *Standard Alloy*

182. High Speed Steels
Catalog of grades, applications, heat treatment of high speed steels. *Vanadium-Alloys Steel*

183. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

184. High-Temperature Alloy
12-page booklet on fabrication and design data for stainless 330 (35% Ni-15% Cr) and other alloys. *Rolled Alloys*

185. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

186. High-Temperature Belts
24-page bulletin on metal conveyor belts. *Wickwire Spencer*

187. Hydrogen Atmosphere
Bulletin on equipment for supplying hydrogen with oxygen content less than one part per million and dew point to —70° F. *Baker & Co.*

188. Identifying Alloys
Booklet of procedures for rapid identification of more than 125 metals and alloys. *International Nickel*

189. Identifying Stainless
Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. *Carpenter Steel*

190. Induction Heating
Bulletin on low-frequency (60-cycle) induction heating furnace for nonferrous metals. *Magnethermic*

191. Induction Heating
Folder on bench-type electronic induction heating generators. *Induction Heating*

192. Induction Heating
Book contains selector chart and heating and melting speeds for induction equipment. *Ajax Electrothermic*

193. Induction Heating
Data folder on megacycle tube-type machines for soldering, brazing, hardening. *Sherman Industrial Electronics*

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Bulletin F-5301 on details of operation of filter for reclamation of solutions. *Murray-Way*

195. Insulation
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196. Laboratory Furnaces
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

197. Laboratory Furnaces
Data sheets on complete line of laboratory furnaces for metallurgical operations. *Boder Scientific*

198. Laboratory Supplies
Instruments and apparatus for control, research, development laboratories. *Harshaw Scientific*

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"Melting Low-Carbon Stainless Steel" shows advantages in use of new low-carbon chromium alloy for producing extra-low-carbon grades. *Electro Metallurgical*

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48-page bibliography of characteristics of steels at low temperature covers 1904 to June 1953. *Inco*

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Catalog on detector for any kind of metal or alloy. *RCA*

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40-page brochure on Vickers research metallograph. *R. Y. Ferner*

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Bulletin describes the Kentron microhardness tester. *Kent Cliff Laboratories*

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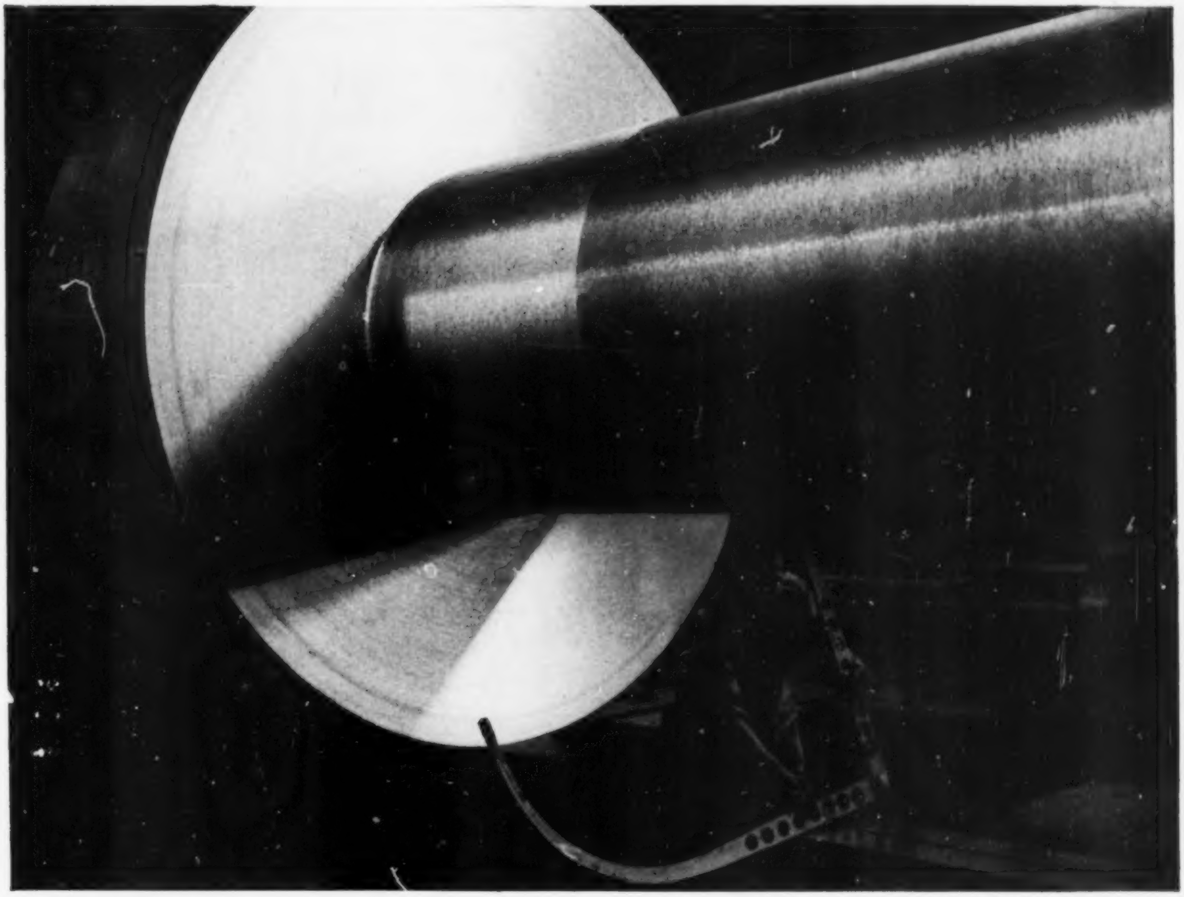
Catalog Micro 8211 on heating microscope for study of melting behavior. *Leitz*



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Data sheet on equipment for determination of modulus of elasticity by sonic method that measures resonance frequency of masses weighing up to 1500 lb. *Electro Products Laboratories*

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Information on sponge iron powder. *Ekstrand & Tholand*

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8-page Progress Report Number 1, "Rare Earths in Iron and Steel M *Molybdenum Corp.*

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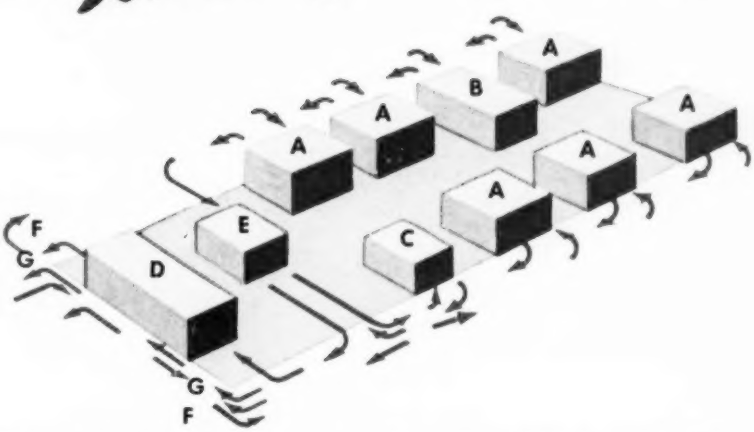

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50-page catalog of industrial X-ray supplies and accessories. *Westinghouse*

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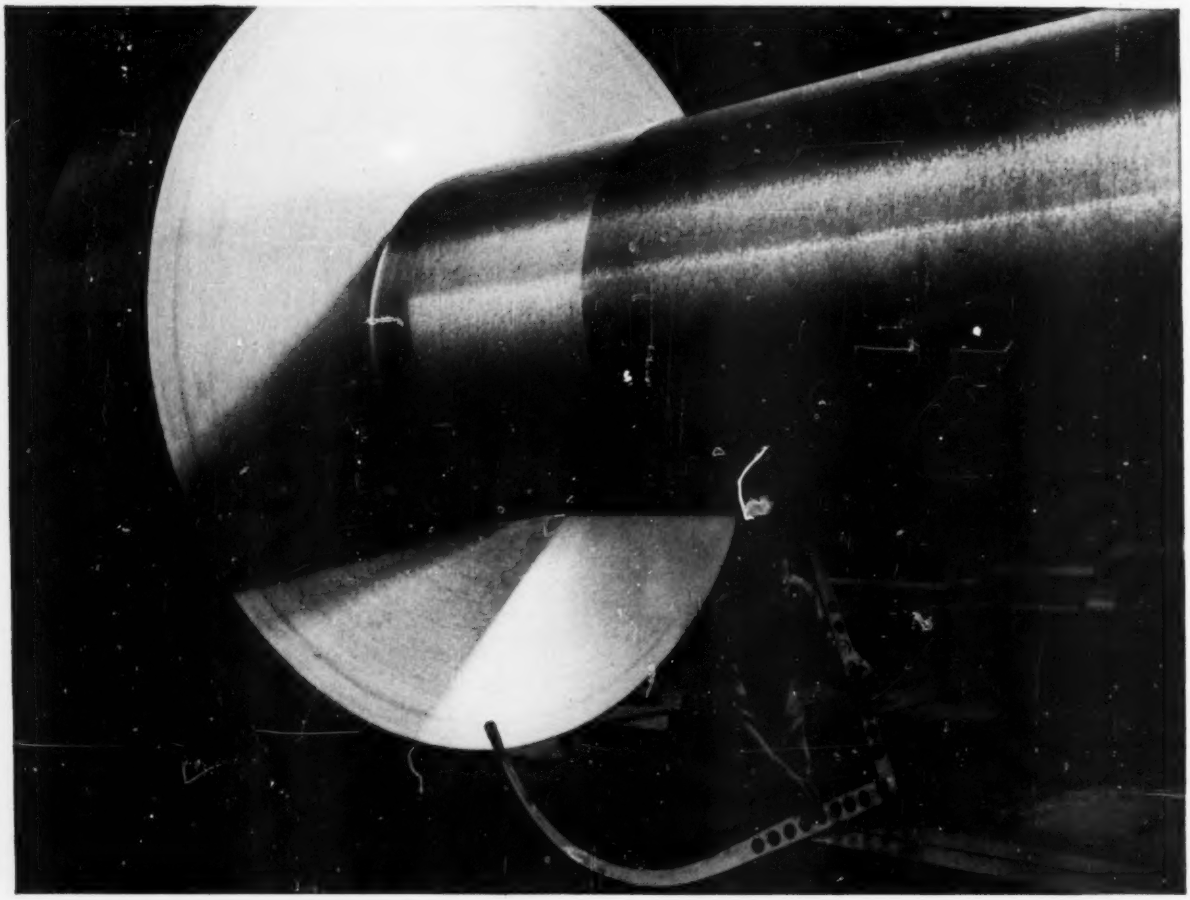

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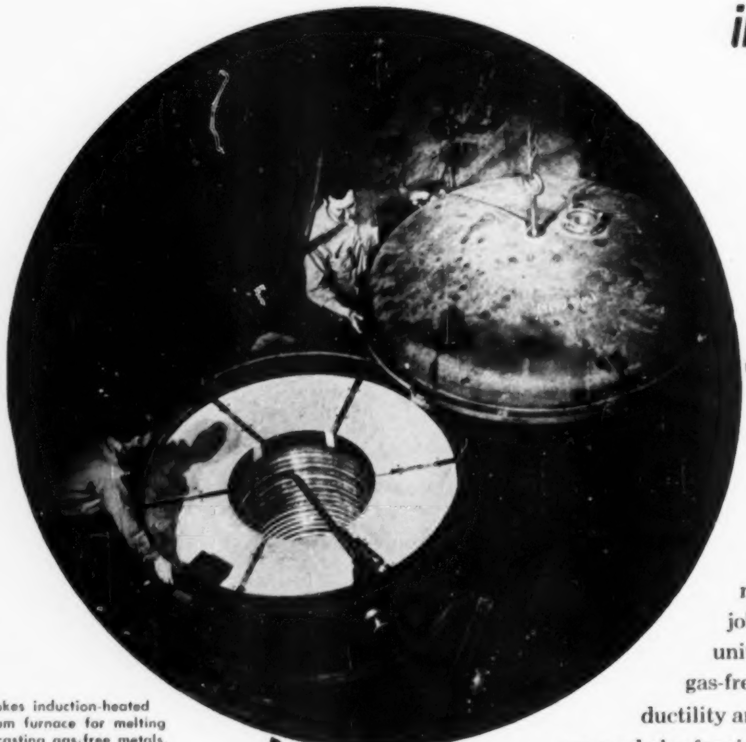

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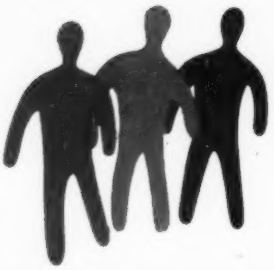

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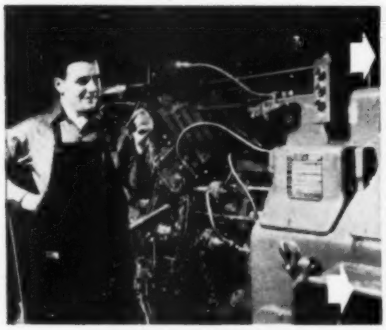

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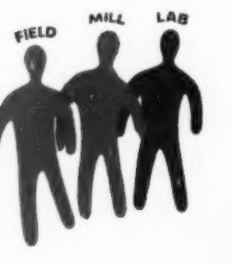
The field metallurgist next talks things over with the Republic Laboratory Metallurgist. His data on tests of alloy steels is added to the material of the field and mill metallurgist.

Then, all three men put their heads together and come up with a recommendation that is the result of pooling their findings and their experience with alloy steels. And since Republic pioneered the manufacture of alloy steels, this recommendation is based on solid data.

The Republic Field Metallurgist passes this recommendation on to your engineers and plant personnel. He works with them to see that your problem is solved satisfactorily, right in your plant. It's his job to see that you get all the advantages out of the alloy steels you use.



The results often include lower production costs, better quality, or even changes in design. You can have this free service by calling your local Republic Steel sales office.

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Dept.: Chrysler Bldg., New York 17, N.Y.

Republic REPUBLIC STEEL
ALLOY STEELS

Other Republic Products Include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing.

Any furnace that needs accurate control

can afford the

Pulse PYR-O-VANE

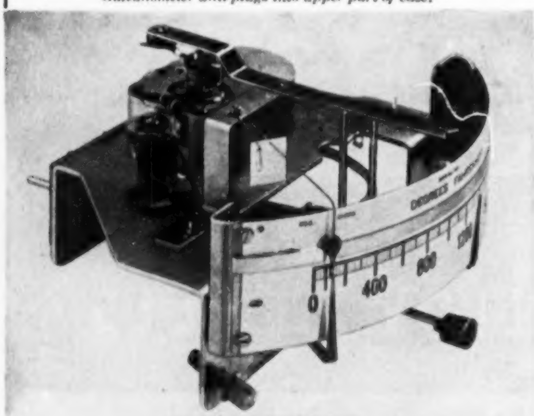
TEMPERATURE CONTROLLER

- provides time-proportioning control
- ideal for electric heating
- applicable to many fuel-fired furnaces
- simple, plug-in design
- economically priced

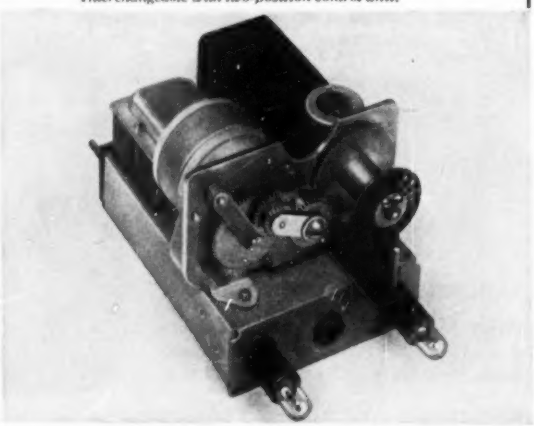
UNIT CONSTRUCTION SIMPLIFIES MAINTENANCE

All the working parts of the *PYR-O-VANE* Controller can be replaced in a matter of a few seconds. Both the galvanometer assembly and the control chassis are plug-in units which slide easily into place. All electrical connections are made automatically when the unit is inserted . . . no chance for wrong connections. Maximum continuity of operation is insured by keeping spare units on hand. In case of trouble, replacement is made so quickly that control is practically uninterrupted.

Galvanometer unit plugs into upper part of case.



Plug-in control unit fits into lower section of case. Interchangeable with two-position control unit.



2 Stainless Parts . . . *look alike*

but with 1 of them

The job becomes profitable

This main shaft for a fishing reel was anything but sport for the manufacturer. The steel used had to have excellent corrosion resistance, concentricity, close and uniform tolerances as supplied, and good machinability. With ordinary Type 416 Stainless, the Company just couldn't produce the shafts at a profit. But when the manufacturer made just *one* change . . . to Carpenter Stainless No. 5 (Type 416) . . . the profit picture changed completely.

Tool breakage is eliminated

Another problem when the ordinary Type 416 Stainless was used, was a serious rate of tool breakage. And here again, just one change . . . to Carpenter No. 5 . . . eliminated this headache.

All requirements are met

With Carpenter No. 5, the manufacturer now reports that *all* requirements are met and the shafts are coming off the line at a good rate. Here's just one more example of the difference Carpenter builds into stainless steels. Specify *Carpenter* on your next stainless order and see the profitable difference all along the line from initial operation to finished part.

Make the one change that counts . . .

change to Carpenter STEEL

Free-Machining Stainless

take the problems out of production

THE CARPENTER STEEL COMPANY, 133 W. Bern St., Reading, Pa.
Export Department: The Carpenter Steel Co., Port Washington, N.Y.—"CARSTEELCO"

For fast delivery, call your nearest Carpenter Mill-Branch Warehouse, Office or Distributor

"PYRODISC"

THE NEW LINDBERG HOT PLATE

At last! A quality, portable hot plate . . . the Lindberg Pyrodisc!

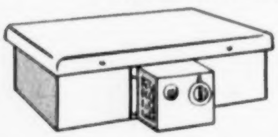
Easily moved with one hand!

Ideal as an auxiliary hot plate for specific job not requiring large capacity, or for the occasional user. And its selling price is only $25.00.

- **Cast-in elements.**
- **"Stepless" control permits extremely precise control of temperatures.**
- **Terminals are protected from spillage and short circuits.**

Diameter, top plate and base, 8"; power rating, 660 watts; power service, 115 volts, 50/60 cycle. Includes cord and plug for easy installation. Shipping weight, 10 lbs.
H-28640—Pyrodisc . . . Each $25.00

If you require large capacity
LINDBERG HOT PLATES
Check this list and



Order now!

LINDBERG HOT PLATES perform varied and routine laboratory jobs, such as boiling, evaporations, and heating. Working temperatures range from 150°F (65°C) to 950°F (510°C). One of the outstanding features of these hot plates is the facility with which the plate temperatures may be raised or lowered to any degree of heat, within the rated temperature range, by means of the Lindberg Input Control.

CHECK LIST	H-28650			H-28655
Unit Number	H-1	H-2	H-3	H-5
Plate Working Surface	10" x 12"	12" x 20"	12" x 30"	5" x 22"
Overall Length A	12¼"	20¼"	30¼"	22⅝"
Overall Width B	12⅞"	14⅞"	14⅞"	9"
Hot Plate Width C	10¼"	12¼"	12¼"	5¹¹⁄₁₆"
Overall Height D	6"	6"	6"	6"
Power Rating (Watts)	1300	2600	3900	1300
Power Service	115-230V 60Cy	115-230V 60Cy	230V-60Cy	115-230V 60Cy
Shipping Weight	35 lbs.	55 lbs.	115 lbs.	55 lbs.
Price	$75.00	$95.00	$126.00	$83.00

HARSHAW SCIENTIFIC
DIVISION OF THE HARSHAW CHEMICAL CO.
CLEVELAND 6, OHIO

Cleveland 6, Ohio 1945 East 97th St.
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News about

UNICHROME
Trade Mark

COATINGS for METALS

Metallic . . . . Organic . . . . Decorative . . . . Protective

Costs reduced in hard chromium plating

Assure protection of zinc with simple finishing

Chemically produced on zinc plate or die castings, Unichrome Dip Finishes inhibit corrosion and withstand exposure. The process uses simple equipment, and adapts for manual or automatic operation. Different solutions produce black, olive drab, brass yellow, iridescent yellow or clear chromate coatings–converting the zinc in 5 seconds to 2 minutes, depending on the solution. More information in Bulletin CC-1.

Easier buffing of copper deposits

Another improvement achieved in the Unichrome Pyrophosphate Process maintains its wide current density range and permits fast, smooth plating over long periods of time. The plate is so smooth that little or no buffing is required. When it is, the copper "flows" under the buff wheel, minimizing the time and work. As a pyrophosphate solution, Unichrome Copper poses no cyanide waste disposal problems. More data in Bulletin CU-2.

Plastisol coating outlasts metal 4 to 1 in corrosive application

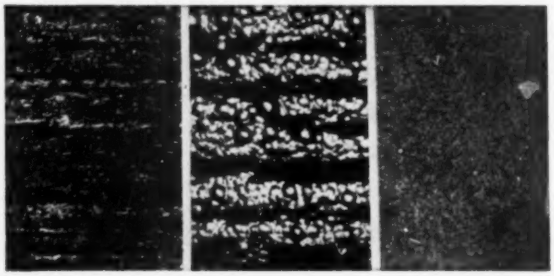
Here's a case showing the extraordinary protection that can be given to metals.

Bleach reduction chambers of a noted chemical producer were coated with a Unichrome Plastisol Compound. This user reported that the coating gave 4 times longer service than even special alloy metals before requiring maintenance! The exceptional chemical resistance displayed by these vinyl coatings is fortified by the thickness they develop–up to 3/16". Tough and elastic, they bake to stable form at 350° F. The Technical Service Department of United Chromium can be consulted on the suitability of these compounds for any specific application.

UNITED CHROMIUM, INCORPORATED
100 East 42nd St., New York 17, N. Y.
Detroit 20, Mich. • Waterbury 20, Conn.
Chicago 4, Ill. • Los Angeles 13, Calif.
In Canada:
United Chromium Limited, Toronto, Ont.

New economies found through unusual chromium deposits produced by Unichrome SRHS Bath

A NEW ENGLAND manufacturer, plating dies and plugs in the Unichrome SRHS Chromium Bath instead of the ordinary bath, found that tool life was being substantially increased. At the same time, plating time had been cut in half.



Untreated steel | *Plated in ordinary bath* | *Plated in SRHS Bath*

This case highlights the essential improvement that has been made since the advent of SRHS Chromium Solutions–that it is now possible to plate at *higher* speed and still get far *smoother* deposits than heretofore.

These advantages are well known in the field of decorative plating. But the unusual nature of the deposits and the speed become all the more striking when "hard" or relatively thick plating is done.

PHOTOMICROGRAPHIC EVIDENCE

The photomicrographs above show the reason why the Unichrome SRHS Solution produces a smooth plate. With unusual "leveling action," this bath smoothed over the minor surface irregularities–while producing a 40% thicker plate than the ordinary chromium bath, in the same time, and under the same conditions.

Such a deposit saves grinding and polishing. This saving cuts required deposit-thickness which still further reduces plating time.

ANOTHER REASON FOR SPEED

Unichrome SRHS Chromium Baths have wider bright plate range. As a result, full advantage can be taken of higher operating curent density for fast deposition of metal without burning on projections. Deposits also show little or no evidence of "treeing," even at high speeds.

MINIMUM EFFECT ON STEEL

Chromium plating increases steel's resistance to corrosion and wear. But it is known also to reduce its fatigue limit. Research shows, however, that high strength steel plated in SRHS Chromium suffers the smallest loss of fatigue strength. This is clearly shown by these tabulated results from an independent university laboratory on heat-treated test specimens plated with .001" of chromium.

Chromium Plating Solution	*Fatigue Strength psi*	*% Loss Over Unplated*
Unplated	81,500	--
Ordinary	60,500	25.7
SRHS CR-100	75,200	7.7
SRHS CR-110	75,300	7.6

Hard chromium plating in the SRHS Bath, therefore, can enable designers to specify lighter parts or smaller cross sections while maintaining the usual safety factors. Platers are finding more and more of their industrial customers *specifying* SRHS Chromium Plating for this reason.

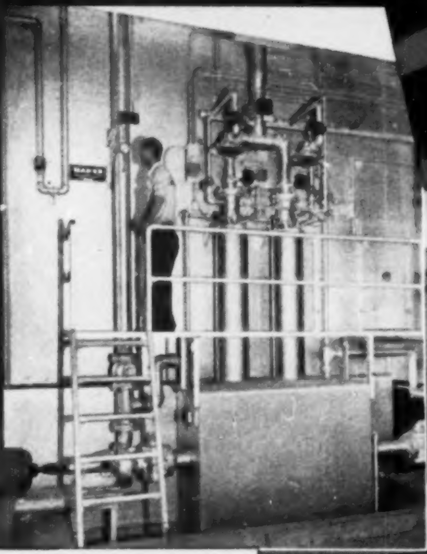
• • • •

While it's still chromium, you can see there's a distinct difference when it's deposited from a Unichrome SRHS Chromium Bath. In addition, the bath offers operating advantages: It can regulate itself, minimize control problems, and maintain peak plating balance. With higher cathode efficiency, it also cuts power requirements and increases capacity without extra equipment.

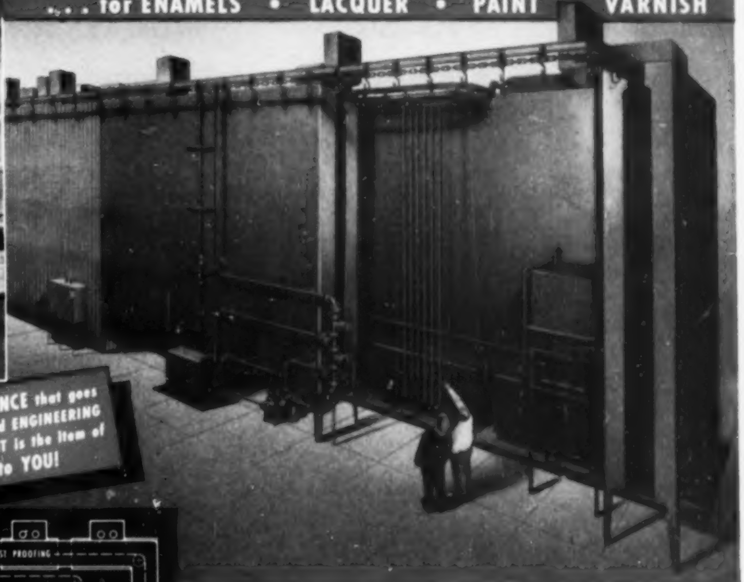
Write or phone for more data. Or better still, ask a United Chromium finishing engineer to give you all the facts.

COMPLETE *Finishing* SYSTEMS

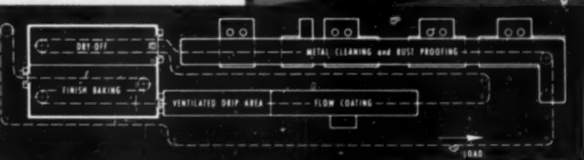
. . . for ENAMELS • LACQUER • PAINT • VARNISH

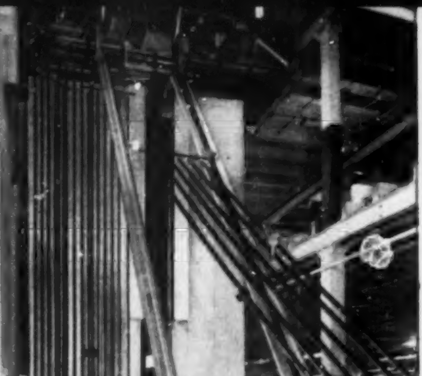


Mahon FIRE-JET Heating Units on the solution tanks of Mahon Five-Stage Metal Cleaning and Rust Proofing Machine—part of the Complete Mahon Finishing System at MULT-A-FRAME Division of Ainsworth Manufacturing Corporation, Detroit, Mich.



. . . the EXPERIENCE that goes into the PLANNING and ENGINEERING of MAHON EQUIPMENT is the item of GREATEST VALUE to YOU!





Exit end of Mahon combined Dry-Off and Finish Baking Oven showing Automatic Unloading Conveyor Ramp and Belt Type Handling Conveyors on the first floor at the Ainsworth Plant.

Ainsworth MULT-A-FRAME Channels are Painted in MAHON EQUIPMENT!

When the MULT-A-FRAME Division of Ainsworth Manufacturing Corporation was confronted with a finishing problem, they turned to Mahon for the solution. The product is a box channel 20 ft. long with only a ½" slot in one side—these are cleaned, rust proofed and painted outside and inside. Two hundred channels are finished per hour. Thousands of Fittings, Concrete Inserts and other MULT-A-FRAME parts and accessories are also finished on the same line. The finishing equipment extends from a pit in the first floor to the second floor ceiling. Oven Heating Units, Recirculating Fans and Exhaust Fans are located on the third floor. Automatic loaders and unloaders, with ramp conveyors from the first floor, load and unload the main conveyor which is located 27'-5" above the first floor. This is another Complete Mahon Finishing System designed and built by Mahon to do a specific job efficiently and economically. If you have a finishing problem, or are contemplating new finishing equipment, you will find that Mahon engineers are better qualified to advise you on both methods and equipment requirements . . . better qualified to do the all-important planning and engineering of equipment—which is the key to fine finishes at minimum cost. You will also find that Mahon equipment is built better for more economical operation over a longer period of time. Mahon's background history in this highly specialized field covers thousands of Complete Finishing Systems including Dip, Flow Coating and Spray Equipment for every conceivable product painted on a production basis. See Sweet's Plant Engineering File, or write for Catalog A-654.

THE R. C. MAHON COMPANY

HOME OFFICE and PLANT, Detroit 34, Mich. • WESTERN SALES DIVISION, Chicago 4, Ill.

Engineers and Manufacturers of Complete Finishing Systems—including Metal Cleaning, Pickling, and Rust Proofing Equipment, Hydro-Filter Spray Booths, Dip and Flow Coaters, Filtered Air Supply Systems, and Drying and Baking Ovens, Cooling Tunnels, Heat Treating and Quenching Equipment for Aluminum and Magnesium, and other units of Special Production Equipment.

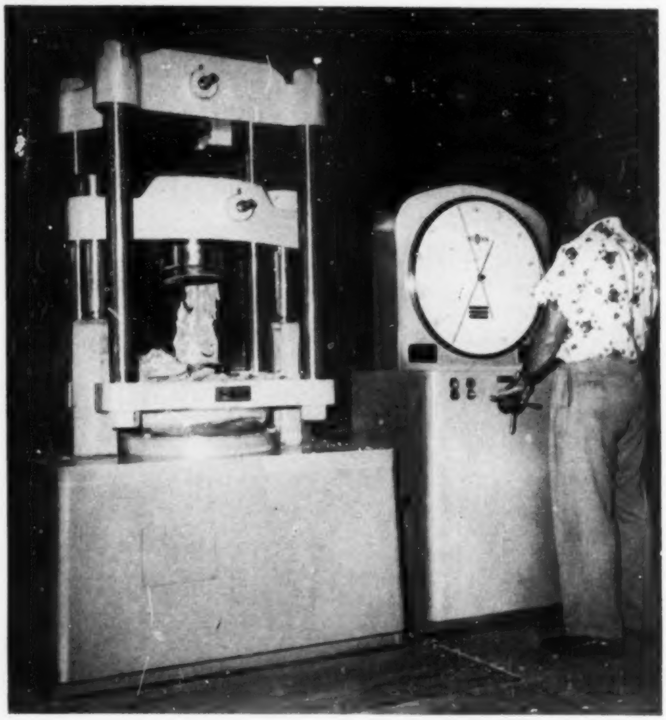
MAHON

At the famous Fiat automobile factory in Turin and at the Innocenti plant in Milan, Lindberg conveyor production brazing furnaces are being used for low temperature silver brazing . . high temperature copper brazing . . sintering of powdered metals . . and bright annealing. For details and "case history" information contact your nearest Lindberg representative.

LINDBERG FURNACES

LINDBERG ENGINEERING COMPANY
2448 West Hubbard Street, Chicago 12, Illinois

A SAFER HIGHWAY IS BORN!



A 300,000 lb. Standard Super "L" applies a crushing load on a concrete cylinder in the South Carolina State Highway Department laboratory at Columbia. Other types of road materials, reinforcing bars, etc., are also tested in a continuing program to assure better highways for today and tomorrow.

As the cost of new highways soars up to a million dollars a mile, the proper selection of road materials is paramount . . . materials which will withstand the rigors of swelling traffic volume, higher speeds and increased payloads.

Long before the bulldozers clear the way, road materials are tested and re-tested before final specification is made. Today in Highway Department laboratories all over the country, Olsen Super "L" universal testing machines are playing an important role. Their dependable accuracy, speed and testing convenience pay tangible dividends that mean better, safer highways.

Whatever your physical testing program, an Olsen Super "L" is worthy of your consideration. Only an Olsen Super "L" gives you a 50 to 1 spread of testing ranges . . . exclusive Selec*range Indicating System . . . instant change of ranges with the flip of a switch while under load . . . and many other exclusive Olsen features.

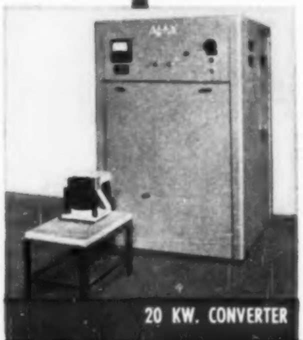
Details are given in Bulletin 47. Write for your copy today.

TINIUS OLSEN
Testing & Balancing Machines

TINIUS OLSEN TESTING MACHINE CO.
2030 Easton Road · Willow Grove, Pa.

Starting Point For Better Melting

AJAX-NORTHRUP CONVERTER-TYPE FURNACES


20 KW. CONVERTER


STEEL


BRASS

These compact, efficient furnaces are used in all leading metallurgical laboratories, and by the major producers of precision castings.

"Almost every new alloy since 1916 started in an Ajax-Northrup furnace."

The 20 Kw. converter will melt 17 pounds of steel in 40 minutes. Maximum capacity is 30 pounds of steel, or 60 pounds of bronze. The larger 40 Kw. unit melts faster, will handle up to 50 pounds of steel. The 6 Kw. unit melts a pound of steel in 8 minutes.

All units may be used for heat-treating, forging, sintering or other applications—no problem to change from one to the other.

Ajax-Northrup converters are completely self-contained. They can be placed anywhere in your plant where water and power are available, require no special foundation or wiring — and they're certified to meet F.C.C. regulations.

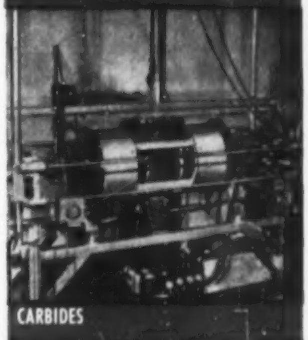
Many of today's "blue chip" industries started with a 20 Kw. Ajax-Northrup converter.

AJAX ELECTROTHERMIC CORPORATION
Ajax Park, Trenton 5, New Jersey

Associated Companies

AJAX ELECTROMETALLURGICAL CORPORATION
AJAX ELECTRIC FURNACE CORPORATION
AJAX ELECTRIC COMPANY, INC.
AJAX ENGINEERING CORPORATION


RESEARCH


CARBIDES


GOLD

AJAX NORTHRUP

INDUCTION HEATING AND MELTING

Since 1916

151

Here's what you've been waiting for...

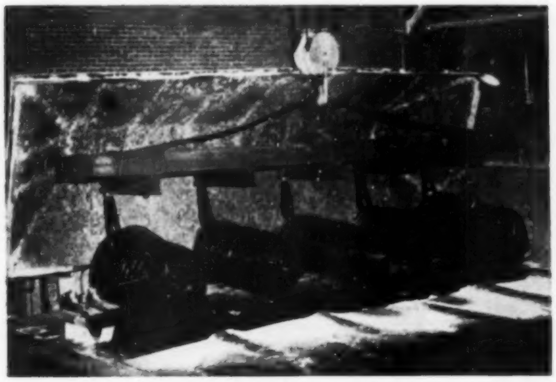
EXLO

–new low-carbon ferrochromium....

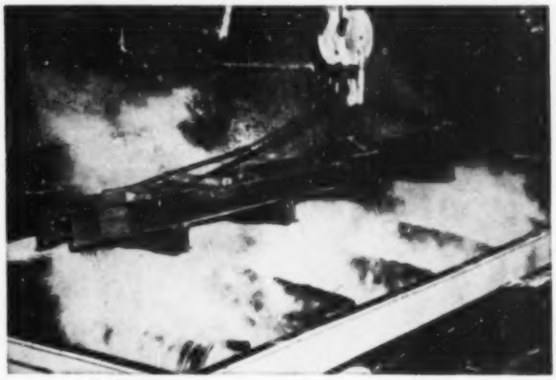
EXLO

is produced in a completely new plant which Vanadium Corporation has recently added to its existing facilities at Graham, West Virginia.

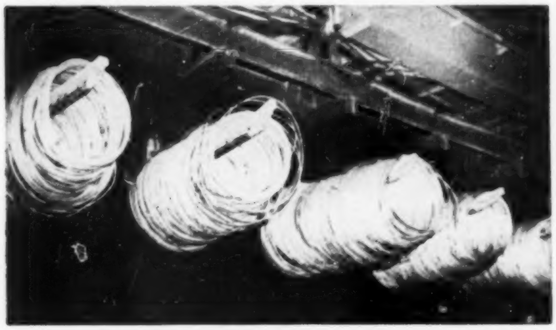
Descaling 5 tons of stainless wire *IN 15 MINUTES* with VIRGO® Descaling Salt



10-MINUTE IMMERSION in molten bath of Virgo Descaling Salt at 900°F. loosens scale. The bath is self-regenerating, and produces no toxic fumes. Immersion time and temperature are flexible, need not be watched closely.



WATER QUENCH removes much of the loose scale. The steam generated by immersing the hot metal in the water further loosens scale by its blasting action. The work is thus prepared for the final acid dip.



THREE-MINUTE DIP in dilute acid removes the now soluble scale. The work is ready for a rinse or hosing to wash off the acid. **Result:** a chemically clean surface—no pitting, etching or metal loss. TOTAL TIME—15 MINUTES.

SEND FOR THESE BULLETINS—Get the whole story on Virgo Descaling Salt and Virgo Molten Cleaner—what they are, how they work, their advantages, how they fit your operations, and the Hooker services you enjoy as a user of the process. Send for these bulletins today.

VIRGO DESCALING SALT—Producers and fabricators of stainless and alloy steels use Virgo Descaling Salt to quickly, positively remove scale produced by hot rolling, forging, extruding, casting, annealing.

VIRGO MOLTEN CLEANER—quickly, positively desands and degraphitizes castings; removes grease, dirt, chemicals, paint, enamel, rubber, atmospheric corrosion and other impurities.

This process can be used on steel; castings; forgings; fabricated parts; material to be salvaged. It employs simple equipment, and is easily adapted to your production methods.

Hooker Electrochemical Company
30 FORTY-SEVENTH ST., NIAGARA FALLS, N. Y.

Please send me Bulletins checked: Virgo Descaling Salt ☐
Virgo Molten Cleaner ☐

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HOOKER CHEMICALS ®

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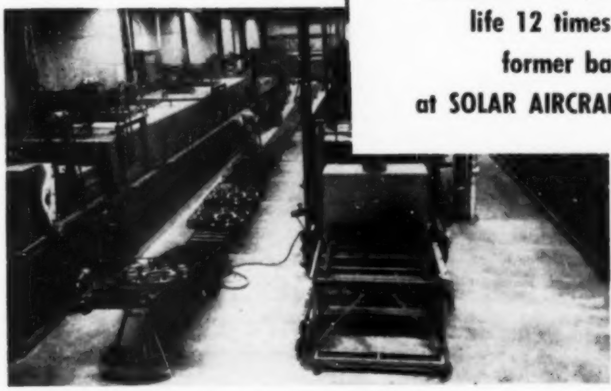
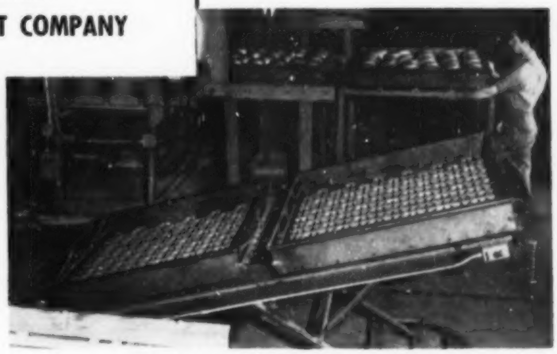
ROLOCK

FABRICATED HEAT AND CORROSION RESISTANT ALLOYS

ROLOCK "Serpentine" basket life 12 times that of former baskets at SOLAR AIRCRAFT COMPANY



Jet burner plates leaving gravity belt for travel thru furnace.



Baskets ready for loading, others entering furnace.

Baskets that carry jet engine parts thru these 73½-foot gas atmosphere furnaces for continuous annealing must withstand the tough maximum temperature of 2150° F. That calls for skillful designing of baskets and use of high heat resistant material. Rolock supplied Incoloy baskets incorporating their exclusive "Serpentine" base design, with rolled sheet on two sides and sturdy round rod on the other two . . . all superimposed and integral with the "Serpentine" fully articulated bottom.

Baskets are 42" x 42" x 6" deep O.D. . . . weight 120 lbs., carrying a load of 200-250 lbs. As a replacement for baskets formerly used at Solar's Wakonda plant at Des Moines the new ones have, so far, given 12 times the service life.

Rolock engineers provide practical solutions of your container problem for heat treating or corrosion resistant processing . . . or will cooperate with your own departments for lower hour-cost designs and methods. We like tough problems . . . and welcome yours. Send them in!

CATALOGS ON REQUEST

Offices in: PHILADELPHIA, CLEVELAND, DETROIT, HOUSTON, CHICAGO, ST. LOUIS, LOS ANGELES, MINNEAPOLIS, PITTSBURGH

ROLOCK INC. · 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

8RL53A

Johns-Manville announces the development of new **SIL-O-CEL 16L** *Insulating Fire Brick...*

Lompoc, California, where Johns-Manville mines and processes diatomaceous silica insulating materials

Combines outstanding physical and thermal properties for furnace service to 1600F

1—has less than 0.1% reversible thermal expansion at 1600F

2—provides high load-bearing strength

3—for direct exposure or back-up service

Check these properties of SIL-O-CEL 16L

Maximum service temperature 1600F, back-up or exposed

Approximate density 33-35 lb per cu ft

Transverse strength 60 psi

Cold crushing strength 350 psi

Linear shrinkage 0.7 percent at 1600F

Reversible thermal expansion less than 0.1 percent at 1600F

Thermal conductivity (Btu in. per sq ft per F per hr at indicated mean temperatures) 0.92 at 500F; 1.07 at 1000F; 1.22 at 1500F

Here is a new development of Johns-Manville insulation and refractory research. Its exceptional characteristics provide important savings in furnace construction. Made of diatomaceous silica, Sil-O-Cel* 16L Insulating Brick is light in weight . . . has low thermal conductivity . . . high structural strength. And where furnace linings are subjected to severe heat shock or where high load-bearing properties are needed, Sil-O-Cel 16L offers outstanding performance.

Sil-O-Cel 16L is now available. Samples will be sent on request. Also available without obligation is Booklet IN-115A, which describes Sil-O-Cel 16L and other J-M Insulating Brick and Insulating Fire Brick for service to 3000F. Write Johns-Manville, Box 60, New York 16, N.Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

*Sil-O-Cel is a Johns-Manville registered trade mark

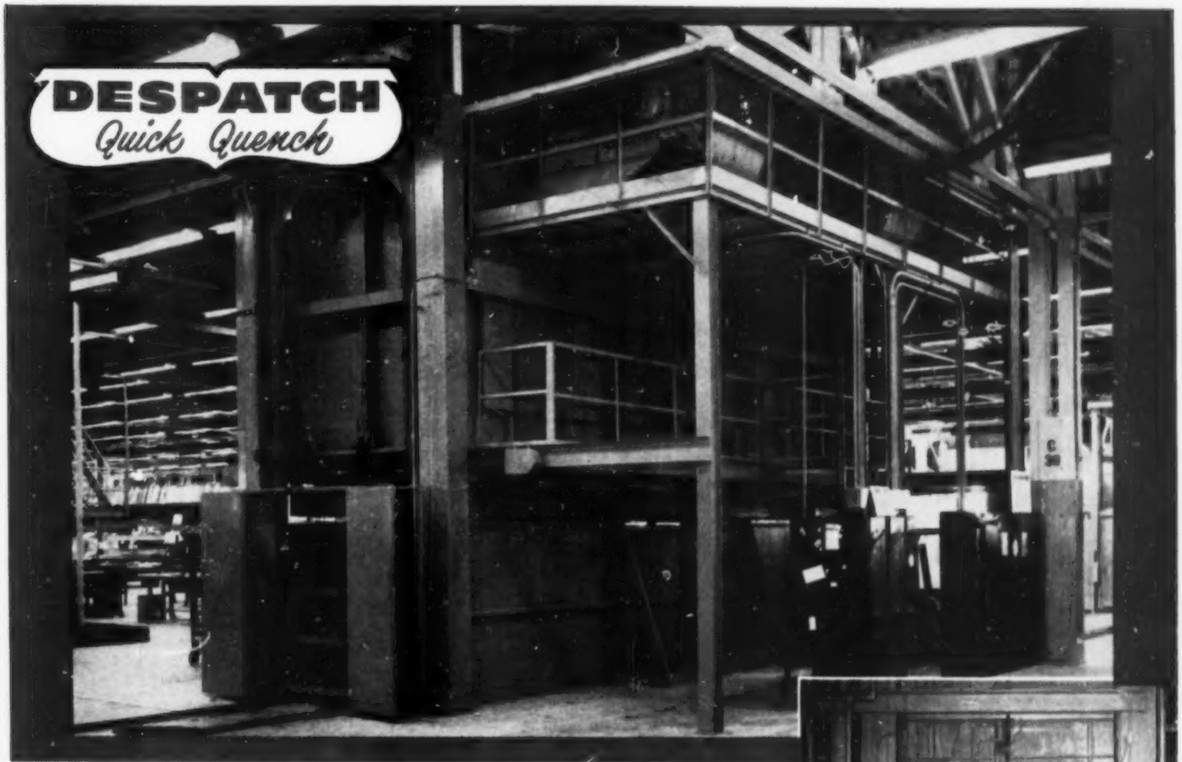
Replaces SIL-O-CEL Natural Brick

The development of Sil-O-Cel 16L Insulating Brick has resulted in the discontinuance of Sil-O-Cel Natural Brick. The outstanding properties of Sil-O-Cel 16L make it the ideal replacement for Sil-O-Cel Natural Brick for back-up use. In addition, the properties of Sil-O-Cel 16L Brick extend its use to exposed service applications.

JM

Johns-Manville *FIRST IN* INSULATION

MATERIALS · ENGINEERING · APPLICATION



THE FURNACE OF PROVEN SPEED AND DEPENDABILITY IN THE SOLUTION HEAT TREATING OF ALUMINUM!

EIGHT SECONDS OR LESS is all the time required from heat chamber to complete quench with this DESPATCH high production aluminum heat treating furnace now operating in the aircraft division of a large automotive firm.

910° F. IN 25 MINUTES: A 426 KW heater has sufficient capacity to raise a 950# aluminum work load plus a 1000# steel rack to 910° F. in 25 minutes. Two high volume recirculating fans of 25,000 CFM each deliver heated air to the furnace, and heat uniformity is assured within a ± 5° F. Furnace is designed to operate up to 1250° F. when desired.

ELEVATORS AND WORK CHAMBER DOORS are hydraulically operated and interlocked with push button controls providing automatic sequence operation thru the complete cycle from heat treating to quench to unload. Furnace takes a work rack 4′ wide, 5′ high and 22′ long.

EFFICIENT FOG QUENCH PREVENTS WARPAGE

An intermediate fog quench at floor level is provided before load is immersed in recessed tank. A series of fog jet nozzles are so arranged as to cover the load completely with a dense fog, a precaution against warpage of certain aluminum parts. The fog quench may be by passed if desired.

PLAN FOR THE FUTURE WITH DESPATCH

DESPATCH ENGINEERS are designing heat treating equipment today with tomorrow's higher production demands in mind. When planning for the future in your plant it will pay you to keep DESPATCH in mind because DESPATCH equipment is tailored to your particular needs to give you the most efficient operation at lowest costs.

Write, wire or call Dept. P

DESPATCH
Engineers, Fabricates and Installs a Complete Line of—
- ★INDUSTRIAL FURNACES
- ★INDUSTRIAL OVENS
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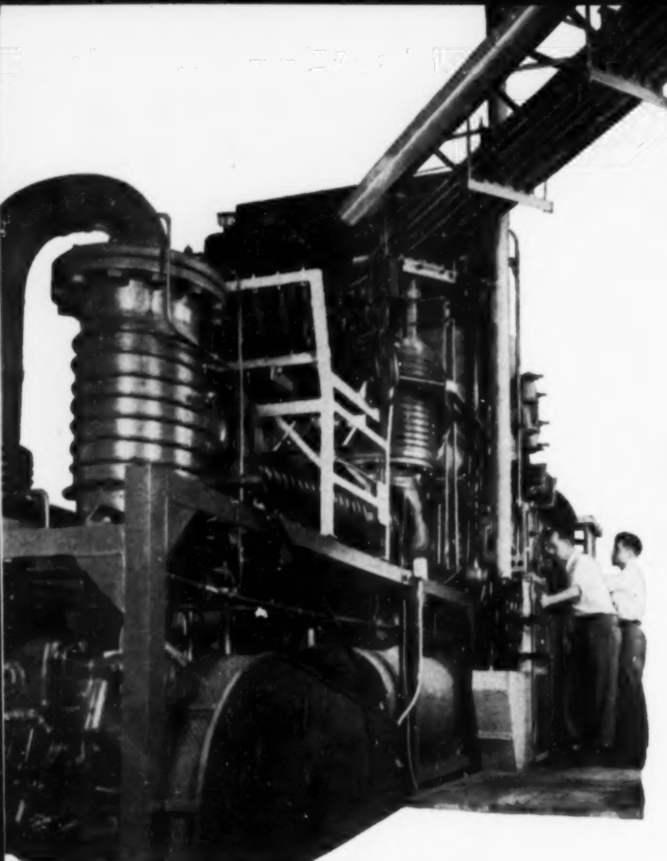

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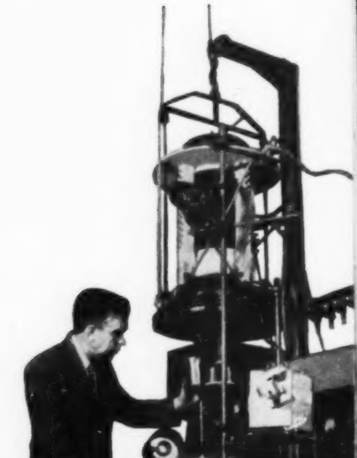

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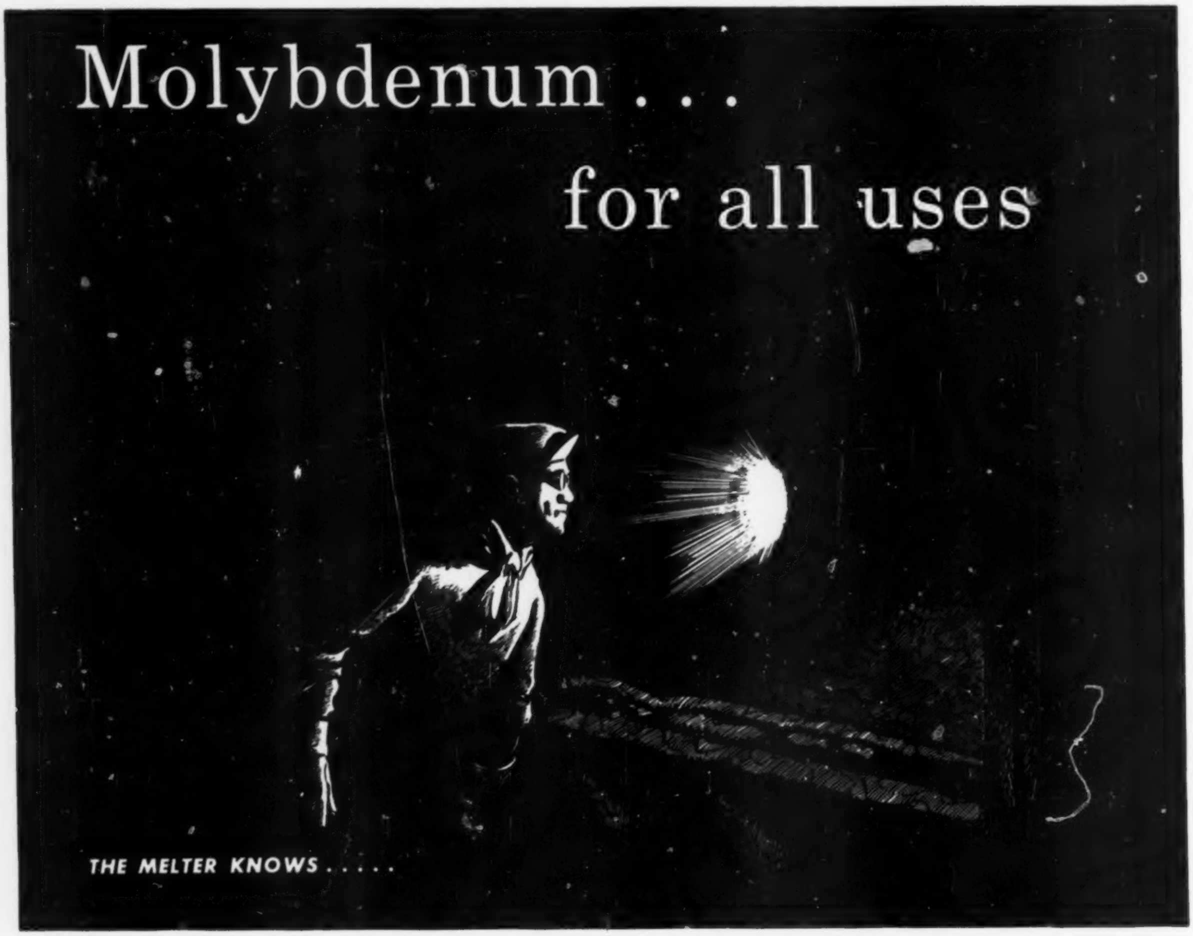
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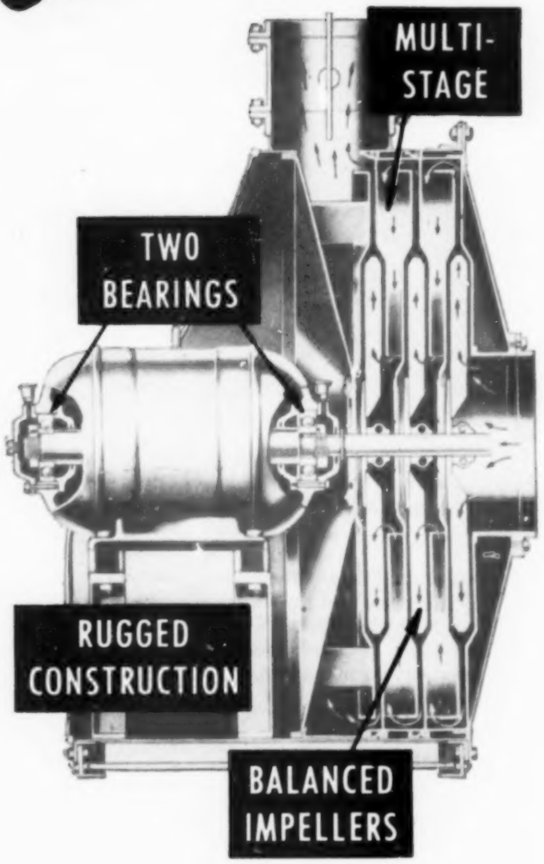

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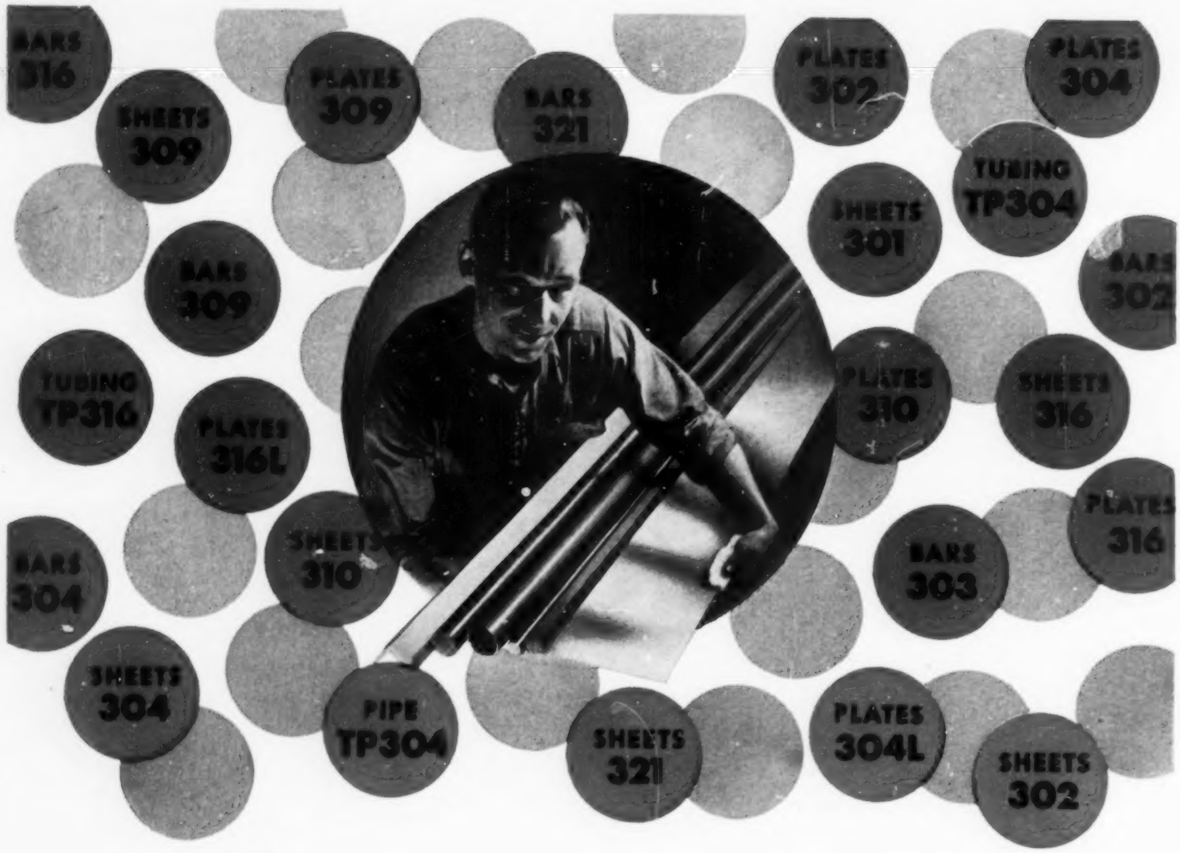

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RYERSON STEEL

Critical Points

by the Editor

A Glimpse of European Metallurgy

It might be well to start this issue of *Metal Progress* – our second effort to produce an annual view of metallurgy on the international scene – with a brief account of a foreign pilgrimage during the late summer. But anything of this sort should be prefaced by a warning that it makes no effort to do more than report one man's recollections of a two-months' tour (part business, part holiday) wherein a few steel and fabrication plants were inspected and a number of men in that branch of the metals industry were visited. Thus it can be, in no sense of the word, a comprehensive review, even of the iron and steel branch.

Throughout free Europe, from Sweden to France and from Switzerland to England (Austria, Italy and Spain were not on the itinerary) even the most casual observer notes a great building boom. Much war damage remains unrepaired in France, Germany and England, especially in residential areas. The traveler sees broken-down bridges everywhere. Even neutral Switzerland and Sweden are still striving to catch up with projects postponed since the war years when nothing more than a bare living was possible. And in Sweden a curious situation exists – at least it will seem curious to anyone who still believes that a quasi-socialistic form of government, as has been long established in Sweden, would impose the very least restrictions on an individual's job, freedom of movement, and pay. Sketched in broad terms, the situation is this:

Sweden must keep its exports moving in order to maintain a balanced economy (to pay for what it buys, in plain words). Swedes must import nearly all their fuel and this they must have. There is also a keen demand for luxuries that make life easier, like automobiles or household refrigerators, and for special industrial tools, readily available from abroad, but not manufactured at home. To pay for these the Swedes export high-grade iron ore and tool-steels, and forest products (pulp wood and paper). To keep these exports moving in required volume the miners, woodsmen and paper-mill hands remain miners, woodsmen and paper-mill hands. The construction industry, able and ready to pay higher wages, is strictly regulated as to its employment practices. The result is that heavy construction (such as the Stockholm subway or the modernization of a steel plant) is long postponed and drags on slowly, once started, while the rather poorly paid woodsman has little chance of becoming a better paid carpenter.

Such are the blessings of a planned economy.

A second lasting impression is that the Germans are as busy as beavers. That was first apparent when driving down the Rhine from Frankfurt to Koblenz, where the river cuts through the highlands, and the bluffs on either shore were once commanded by local barons whose crumbling castles remain to mark their past glories. This valley is the main traffic route from north to south. Double-track railroads are on either bank. Even on a Sunday the traffic on each equaled that on the New York Central's main line. Not only that but the river was alive with barges. At no time were there less than a half dozen in view on the twisting river. Furthermore, they were not the scows you see towed up and down the Seine in France, whose power plant (two horses) is stabled in a shed amidships. They were self-propelled motor barges and tankers of 4000 or 5000-tons burden. All this in addition to the Autobahn – a four-lane super-highway paralleling the river (beyond artillery range) – on which there were more trucks bowling along than the Editor has ever seen on the Pennsylvania Turnpike.

(The Autobahn, by the way, consists of several main lines, crisscrossing Germany from north to south and from east to west, 2100 miles of it in all, perhaps double what we have in America. One non-metallurgical aspect of it is a 3-ft. hedge along the center strip, not high enough to obstruct the landscape by day, but perfect in stopping headlight glare by night.)

A third generalization of direct importance to *Metal Progress* readers is the widespread work on low-grade coke and ore in steelmaking. Europe, for some reasons unknown to the Editor, has much less scrap than America, so the steel industry is based primarily on pig iron. England, France, Belgium, Luxemburg, West Germany, Sweden even – all are facing the problem of making pig iron good enough for the steelmaker with continually poorer raw ma-

terials. So the problem is being attacked simultaneously on several fronts.

Sweden exports its good ores. The poor ones remain for local consumption. Yet Swedish steelmakers must retain their age-old reputation of excellence. So the most varied metallurgical efforts are to be found there. Whether because the Swedes are individualistic or whether their plants are rather small, the widest variety of ore concentration, reduction, and desulphurization schemes are under experimental study or plant operation. Some idea of this may be gained from Prof. Kalling's account on p. 108 of current work at Domnarvet, Sweden's Gary.

Similarly in the Benelux region there is a cooperative investigation which breaks across national lines. Forced by the steadily deteriorating quality of available coke, a low-shaft blast furnace has been designed, built and blown in during the summer. An account of its operating problems and successes is promised for *Metal Progress's* third annual review, a year hence.

This same situation in coal, plus the necessity of smelting very low-grade ore (even though it is self-fluxing) has resulted in some important changes in British ironmaking. At plants of United Steel Companies, Ltd., the ore is crushed and bedded, and then sintered into a porous cake 16 to 18 in. thick. This is excellent blast furnace feed; sintering can be done with the poorest grade of fuel, the cake is easily reduced; very little dust is blown out with the top gases. Coke burden is reduced about 12% and pig iron production is increased by 25%. Some of the functions of the upper part of the blast furnace shaft have been transferred to the sintering machine, so the clear trend is toward a shorter shaft, permitting even weaker coke for fuel, and production of 850 tons a day per furnace from 30% ore or leaner.

Lastly, the Editor would again warn that these observations are but those of one traveler hurrying over a strange landscape. He wants by all means to avoid generalization, the occupational disease of pundits. An example was seen the other day in the Chicago Tribune ("The World's Greatest Newspaper" you know) in an editorial entitled "The Polite American Motorist". It expounded the amazing proposition that "the American is a far more considerate driver than the European". My brief experience convinced me that only in the major cities is the traffic density anywhere near as high as in America. The European (that is, the "average" European, if there is one) doesn't drive a car. Next, anyone who says that the Frenchman (Parisian) on wheels, whether it be Renault, motorcycle or bike, is nearly as considerate as the corresponding Englishman (Londoner), is so blind to differences that he would confuse a Sioux with a Creole.

The Editor of *Metal Progress* and Walter Jessup (Editor of *Civil Engineering*) were recently crossing over the enormous valley of the Snake River in Idaho and their conversation naturally turned to stupendous things in engineering. My list of seven, the best I remember seeing, was (in no particular order):

New York Subway System
Grand Coulee Dam and Power Plant
San Francisco Bay Bridges
Utah Copper Mine, Mill and Smelter
Washington Monument
Union Pacific Railroad
K-25 (Diffusion Plants at Oak Ridge)

What's yours?

Metallurgical Activities in Japan

By DANIEL J. MURPHY,
Colonel, Ordnance Corps
United States Army

IT HAS BEEN a refreshing and enlightening experience to note the active metallurgical research throughout Japan. Ample opportunity to view current Japanese efforts came about through the interest of the United States Army Ordnance Corps in the metallurgical potential of Japanese industry. The major plants producing ferrous and nonferrous metals, their research establishments, including those of the larger universities, were visited and discussions were held with many of Japan's foremost metallurgists. Many of them had studied in or had visited the United States and held active membership in the ⊕ and other American engineering societies. Prominent among them were members of the Japan contingent to the World Metallurgical Congress sponsored by the American Society for Metals.

It may be said without hesitation that these men are proud of their association with the American metallurgical world, and are striving to advance with great earnestness and purpose.

Metallurgists in Japan, much as in America, educated in the main at government universities, stay as instructors or researchers or join the staffs of research laboratories, small and large, throughout the many companies

Metallurgical Careers in Japan

which make up Japan's industrial structure.

Unlike Americans, once retained or employed, a Japanese professional man becomes dedicated to his particular firm for his full career. It is extremely rare than an individual leaves one firm to go to another. A mutual fidelity underlies this tradition, stemming from the most careful preselection by private firms of future professional employees while still in undergraduate status; their academic development is sponsored as well as their growth to stature in professional life. While this fosters a close-knit organization and enhances industrial competition, it also retards the exchange of information between technical men for the common advancement.

University Activities – This tradition does not reach into the universities. The latter are almost entirely government owned and their faculty members are employees of the government. Here the interchange of ideas flourishes. University men participate actively in the various technical engineering and scientific societies, though personal contacts with foreigners are minimized by the great distances involved and inadequate funds. Even travel within the country is considerably restricted. Interchange of information is accomplished in large measure through publications of the journals of the national societies. The latter parallel those in America and correspond in activity.

It is not uncommon for staff metallurgists of industrial concerns, especially the larger ones, to participate in society activities. In fact, their attendance at the public meetings is generally larger than that of faculty members due to the close budgeting of university funds. The more prominent industrial concerns publish technical journals of their own, containing papers by their own staff members.

Japan's progress in modern metallurgy stems from the Institute of Metals at Tohoku University, established in 1916 by Kotaro Honda, honorary member ⊕, now generally called "the father of metallurgy in Japan". He gathered into this institute several assistants who have since become widely known for their individual contributions, and under his brilliant leadership the institute grew continuously, and by 1945 was recognized everywhere as the center of metallurgy in Japan. Even abroad it was well thought of for the important publications appearing regularly in *Science Reports*.

Organized under the two fields of fundamental research and industrial research, it sponsored work in physical metallurgy, metal physics, low-temperature physics, semiconductors, magnetic alloys (where extraordinary discoveries were made), metal chemistry, low-temperature chemistry, corrosion and its prevention, steelmaking, alloy steel, light alloys, and radiation metallurgy, as well as melting, casting, forging, working and heat treatment of metals generally, powder metallurgy, metal spraying, and electrolysis. Prior to damage from Allied bombing in 1945, the institute occupied laboratories totalling 100,000 sq.ft. in floor area. Wartime losses are now being restored, and the scientific services of the institute continue to

Fig. 1 – Japan Steel Works, Ltd. in Hokkaido, the Northern Island of the Japanese Archipelago

keynote metallurgical activities throughout Japan. Members of the institute staff, dedicated to science rather than financial gain, cut across competitive and proprietary lines in furnishing consultative advice to industry.

WARTIME STUDIES

During World War II, of course, the various governmental agencies sought to mobilize metallurgical research, but lack of coordination by the military prevented effective work. The principal efforts were directed toward utilization of low-grade raw materials and substitute alloys to relieve critical shortages, first of nickel, copper and cobalt, and later of practically all industrial metals. The wartime trend in the use of heat treatable Ni-Cr steels was toward Ni-Cr-Mo, then to Cr-Mn, and next to Cr-Mn-Si. Toward the end of the war even chromium and manganese were scarce, and plain steels had to be used, forcing the designer to allow for the use of heavier sections.

Investigations were also conducted in the field of armor plate, gun steel and metal components of ammunition. Nondestructive tests for armor plate and the effects of alloying elements were studied, including the effects of phosphorus, silicon and zirconium. No beneficial effects were reported for zirconium. As much as 6% tungsten was put into gun steels – though with considerable difficulty – and marginal improvement was found. Chromium plating of gun barrels was found to reduce wear.

The shortage of brass stimulated extensive effort with steel cartridge cases along the lines of German experience, information on which was available to Japan. Single-piece cases were generally used, though two-piece designs were made where pressures were not too high. Considerable difficulty was encountered in the drawing operation; rejections often ran as high as 35 to 40%.

A considerable amount of fundamental research was carried out during the war years, particularly by civilian metallurgists whose systematic analyses of various alloy systems have resulted in the accumulation of a large amount of basic data. Among these studies were those by Murakami and Imai of the Institute of Metals on the effects of eleven different alloying elements on the isothermal transformation of steel. They used magnetic analyses to separate the magnetic critical points of carbides and they concluded that peculiarities in the S-curves were due to differences in the type of carbides which separated at different temperatures.

Research on Low-Grade "Iron Sand"

Since the war rapid strides have been made toward getting back on a sound footing. Metallurgists, diverted by war into other efforts, have now returned to their field of interest in university or industry. There is a great effort to catch up with progress outside of Japan. One impediment rests in the almost total lack of copies of technical literature published in America and Europe during the war. All would welcome assistance in this regard.

POSTWAR PROGRESS

The recovery and regrowth of Japan's civilian industry has stimulated many new processes and much improvement of product in many ferrous and nonferrous plants throughout the country, catering to both domestic and foreign trade. This has stimulated considerable metallurgical research, both fundamental and applied, the soundness and thorough-going nature of which were readily apparent to this observer.

Japan has a number of deposits of "iron sand" analyzing about 15% Fe. Unfortunately they also carry up to 30% titanium oxide and appreciable quantities of arsenic. Considerable attention has been, and is still being given to methods of concentrating these low-grade ores. One method charges a magnesia-lined electric furnace with a flux of lime, silica, manganese ore, slag and coke, and obtains a 70% recovery of iron, low in carbon. Another method charges concentrated iron sand and coke but little flux, and yields pig iron containing 3.5 to 4.0% carbon. There are many other interesting suggestions, studied on a laboratory scale, but as yet there seems to be no economic solution to this most difficult problem. Meanwhile at least three quarters of the iron ore (and nearly half the coking coal) must be imported.*

In the field of steelmaking, both basic and acid openhearth processes are under close study by all plants. Detection, effects, and control of oxygen, hydrogen, sulphur, and nonmetallic inclusions are receiving attention. One unique method applies thin films of cellophane to the surface to trap hydrogen gas evolved at room temperature from steel forgings. Quantitative studies by Dr. Shimoda of the rate of hydrogen evolution seek to relate its diffusion to the appearance and cause of flakes in steel. Evolution of hydrogen seems to be proportional to hydro-

* EDITOR'S NOTE–This situation was discussed at some length in "Metal Industry in Japan" in *Metal Progress* for January 1953, p. 112.

gen content and the rate proportional to the applied stress.

Dr. Shimoda has also investigated the characteristic grain structures of acid and basic steel. Fairly uniform grain refinement was observed in acid steel – much more nonuniform in basic. He believes that the refining reactions in acid furnaces are slower but more complete than in the basic. Furthermore the effects of chromium on nonmetallic inclusions in molten steel also seem to differ according to the steelmaking process, and are attributed to the relatively larger solid solubility of SiO_2 in the chromium complexes under acid open-hearth conditions.

Among current studies of steelmaking is the Swedish proposal for stirring molten steel electromagnetically by an induction coil attached to the furnace bottom.* It attempts to reduce melting time by accelerating the chemical reaction between the molten steel and slag, thereby cutting power and labor costs, and producing steel of higher and more uniform quality with less inclusions. Increase of 20% in annual output and reduction of 3% in ingot costs are reported. A 2-ton electric furnace, 1200-kva. transformer and 50-kva. stirring device are employed.

Further efforts are being directed toward the coating of ingot molds with molten slag. A special slag is formed (50% SiO_2, 15% MnO, 20% CaO, and 15% MgO), melted and poured into the ingot mold just ahead of the molten steel. It floats up on top of the rising metal, and a little freezes continuously against the mold wall into a readily strippable shell around the solidified ingot. Such a smooth surface is produced on the ingot that scarfing is practically eliminated and the life of the ingot mold is multiplied severalfold.

Heating of the ingot head by an electric arc eliminates shrinkage and pipe to such an extent that yield is increased by a reported 20%. Further study is being directed toward simplifying the automatic devices and adjusting voltage and current to the ingot size.

Nonferrous Metals – As in the field of ferrous metals, so also is there considerable activity in the nonferrous field. The demand for cable and transmission lines has stimulated investigations on copper and copper alloys and the production of many varieties of built-up, multiple and coaxial cables. Continuous casting of copper and aluminum is done on a production basis. Directional properties, hot workability, deoxidation methods, corrosion and erosion resistance, grain size effects, stabilization and age hardening are all receiving attention in work now in process. In one modern laboratory, a well-designed arc melting furnace for producing pure titanium ingots in argon atmosphere was observed. These ingots were used in the study of fabrication properties, both hot and cold forming.

While fundamental research could be found

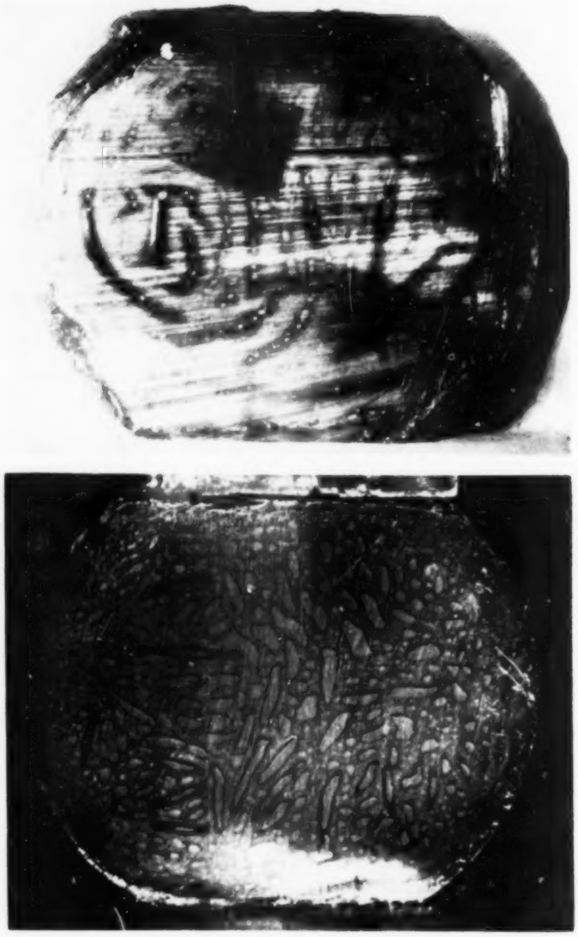


Fig. 2 – Section of Large Steel Billet, With Cellophane to Trap Hydrogen as It Is Evolved. Above: Condition after some hours at room temperature. Below: Evolution speeded when the metal is squeezed at 14,000 psi. (Courtesy Japan Steel Works, Ltd.)

* Editor's Footnote – See brief note on this device installed by Timken Steel & Tube Division, *Metal Progress*, February 1953, p. 87.

in most of the laboratories I visited, to a greater or lesser degree depending upon the size, capital, and incentive of the industrial organization supporting them, by far the greatest activity is at the Institute of Metals at Tohoku University in Sendai. Here a well rounded staff is energetically studying problems throughout the whole range of physical metallurgy and metal physics. There is keen interest in ferromagnetic alloys – stemming without doubt from the early discovery of the K. S. magnet steel* by Honda in 1916. Continued research by him and his associates produced the new K. S. magnet steel* in 1931, and Sendust*, a magnetic core material, in 1936. In 1941 Dr. Masumoto, currently the director of the institute, discovered "Alfer", a 13.2% aluminum alloy of iron; though containing no nickel, its magnetostriction characteristics are reported to be almost equal to those of nickel, its dynamic properties superior, yet it is considerably lower in cost. Other discoveries were an improved Permalloy and the M.S. alloy, a ternary of iron, nickel and chromium, suitable for magnetic shunts.

Fig. 3 – Japan's Largest Copper and Brass Mill. (Courtesy Furukawa Electric Co., Ltd.)

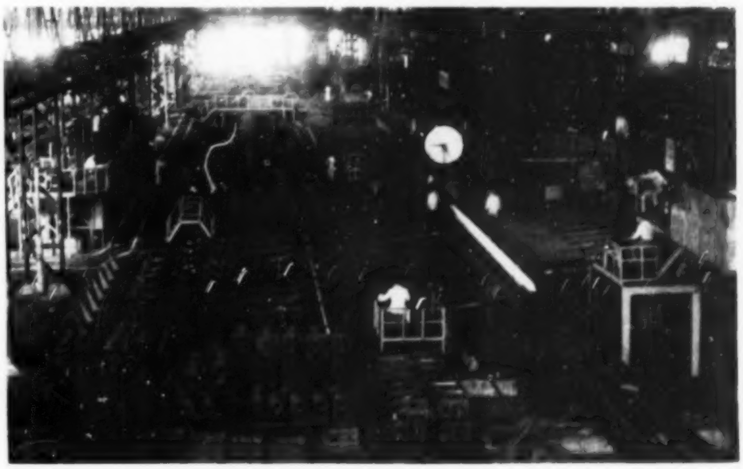
In addition to his work in ferromagnetic alloys, Masumoto has developed several alloys of the invar type which exhibit very small expansion coefficients. Thus, the institute continues to deserve its prewar reputation as a center for information in the fields of magnetic and invar alloys.

Summary—It can be seen that the activity now evident in Japan augers well for a promising future in the field of metallurgy. While the absence of a sovereign government in the years following the war prevented any central fostering of research, this condition now takes on a brighter aspect. A National Institute for Research, sponsored by the Government, indicates a reawakening to the value of research in bringing about a better future. This organization may be expected to enjoy the advisory service of Japan's foremost scientists. Their attention and the cultivation of a balanced program should eliminate gaps or neglect of pertinent research areas, and insure the coordination and integration of isolated efforts of individual scientists and groups.

In any event, work now in process and research to come are deserving of watchful attention by Americans. Publications in American journals, exchange of visitors, or other forms of mutual interchange of technical information will further stimulate scientific advance.

* Typical analyses: K. S. magnet steel – 35 Co, 2 Cr, 7 W, 0.6 C, Fe balance; Improved K. S. – 20 Ni, 15 Ti, 25 Co; Sendust – 10 Si, 6 A1, 84 Fe.

Fig. 4 – Stiefel-Mannesmann Tube Mill Represents Modern Practice (Courtesy Sumitomo Metal Industries, Ltd.)



American Developments in Alloys for High Temperatures

By C. L. CLARK, Metallurgical Engineer
Special Steel Developments, Steel and Tube Division
Timken Roller Bearing Co., Canton, Ohio

Private industry and governmental agencies are continuing their efforts to develop alloys capable of satisfactory operation under ever-increasing temperature and pressure conditions. In fact, during the past few years this phase of metallurgy has probably received as much, if not more, attention than any other. Americans are not alone in this effort; a great amount of work is being done along parallel lines in England and on the continent.

The immediate goal varies from industry to industry and often within the same industry. For example, in the steam power generating field, the present maximum steam temperature in the United States is 1100° F. with 2500 psi. pressure* and the next desired step here and abroad is 1150 to 1200° F. with pressures of 2000 to 5000 psi. On the other hand, in aircraft gas turbines, there is no limit on the wished-for maximum temperature.

*Editor's Note – Slightly higher in Europe, as can be seen by the account on p. 116 of the metals used in two German plants operating at 600° C. (1110° F.).

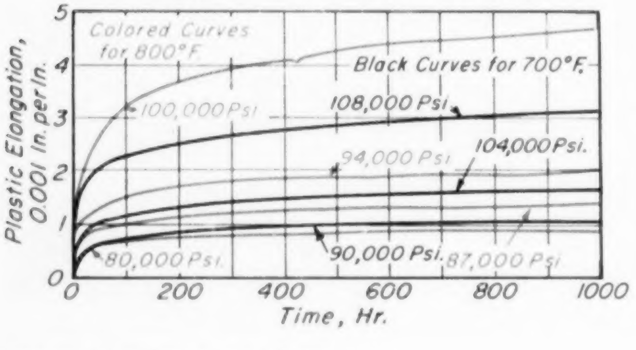


Fig. 1 – Creep Curves Showing Plastic Elongation With Time Under Various Stresses at 700° F. (Black) and at 800° F. (Color). Alloy is "17-22-A" S, a lower-alloy steel with 0.30 C, 0.75% Si, 1.25% Cr, 0.50% Mo and 0.25% V. Heat treatment: normalize at 1750° F., temper 6 hr. at 1200° F. The hardness is 341 Brinell

In the development work on these alloys and their use there has been a somewhat different method of approach depending on whether the intended application is commercial or military. Private industry must consider cost and availability of alloys under emergency conditions to a greater degree than governmental agencies. Likewise the expected life of the equipment is generally much longer, being expressed in years rather than hours. As a result the designers and the metals engineers have had to work more closely together on the non-military applications.

LOWER-ALLOY STEELS

The chief advances in the lower-alloy steels (up to and including the 12% Cr types) have consisted in better use of the steels available. In the steam power generating industry the use of 1.25% Cr, 0.50% Mo and the 2.25% Cr, 1% Mo steels has been extended to 1050° F. in both steam piping and superheater tubes. Consequently, the austenitic steels are seldom used unless the metal temperature is above 1050° F. Thus in a 1050° F. steam plant, Type 321 or 347 stainless is used only in the hottest section (outlet) of the superheaters where the metal temperature would be 1100 to 1150° F.

To illustrate economies that can be gained through cooperation of the designers and metallurgists, the main steam line from the boiler to the turbine may be cited. This generally consists of a single line of 16-in. or larger diameter pipe. In some of the modern higher-temperature and higher-pressure plants, parallel lines of smaller diameter are now used. This not only decreases the fiber stress in the pipe wall and thus permits the

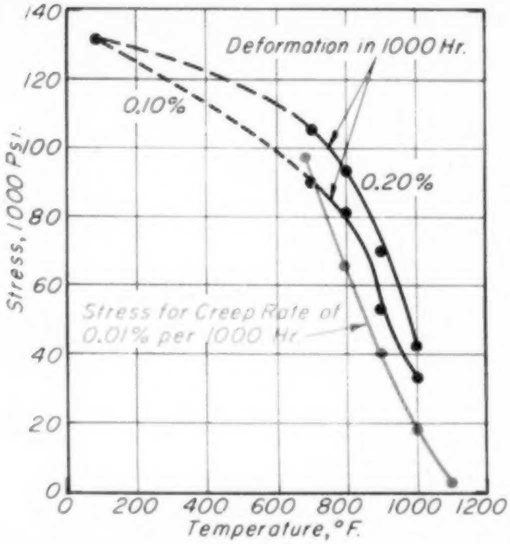


Fig. 2 – Black Curves Show the Stress Required to Produce 0.10% and 0.20% Total Plastic Deformation at Various Temperatures in the "17-22-A" S Alloy of Fig. 1. Colored curve shows the stress to produce a creep rate of 0.01% per 1000 hr. in the 700 to 1100° F. range

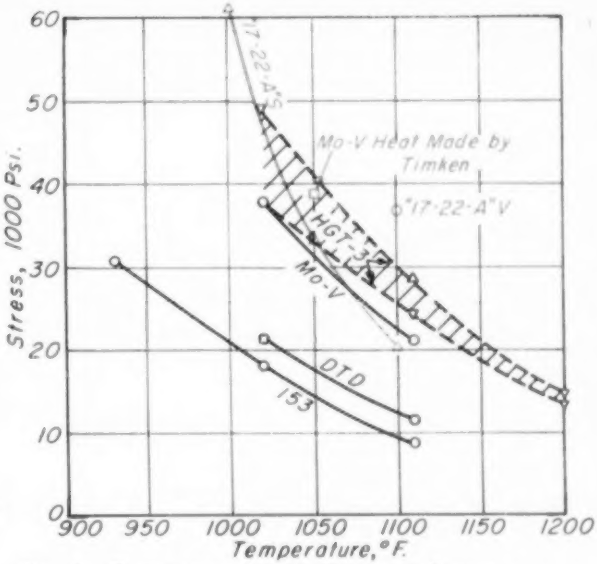


Fig. 3 – Comparison of 1000-Hr. Stress-Rupture Tests on Timken-Made Steels (Color) With English Steels (Black) of the Following Typical Analyses:

	C	Cr	Mo	V
HGT-3	*0.20*	*3.00*	*0.50**	*0.75*
Mo-V	*0.20*	—	*0.70*	*0.30*
DTD	*0.40*	*3.00*	*0.80*	*0.20*
153	*0.35*	*1.10*	*0.80*	—

** Plus 0.50% W in HGT-3*

wall thickness to be decreased, or a lower alloy to be used, but likewise increases the availability of the material because more mills produce the smaller sizes, and eliminates the necessity for using the more expensive forged and bored pipe.

Superheater elements afford another example of the proper use of these lower-alloy steels. The metal temperature of these units increases continuously from the boiler drum to the superheater header. Rather than construct the entire unit of the alloy required to meet the hottest conditions, each unit is composed of a series of steels of increasing alloy content. A typical example for a 1050° F. steam plant would be plain carbon steel, then the 0.50% Mo grade, followed by steel containing 1.25% C, 0.5% Mo and 0.75% Si, next the 2.25% Cr, 1% Mo steel and finally Type 321 stainless steel, listed in order of increasing temperature.

Heat treated (hardened) low-alloy steels are now finding their proper place in the high-temperature field. Until recently, except for bolting applications, they were generally used in the annealed condition. As a consequence the allowable stresses were relatively low – even at intermediate temperatures up to 900 or 1000° F. It is now recognized that certain of these steels possess very high load-carrying ability when properly hardened. (The preferable heat treatment is normalizing and tempering.)

Figure 1 shows time-deformation curves for a heat treated low-alloy Cr-Mo-Si-V steel at 700° F. in black and at 800° F. in color, under stresses ranging up to about 110,000 psi., while Fig. 2 shows the stresses for total plastic deformation of 0.10% and 0.20% in 1000 hr. in the 700 to 1000° temperature range. The load-carrying ability of this steel is remarkably high; for example, the stress to produce a plastic deformation of 0.10% in 1000 hr. at 800° F. is 80,000 psi., and even at 1000° F. it is still of the order of 35,000 psi. It should also be recognized that these properties were obtained when the steel was tempered at 1200° F., well above the testing temperatures.

As a result of these properties this steel is being used as rotors in the compressors of some of the newer aircraft gas turbines where the maximum metal temperature is of the order of 900° F., and in structural parts of these and other engines under metal temperatures up to 1000° F. This same steel is likewise widely used for aircraft brakes; its success in this application depends not only on its high strength but also on its ability to resist heat checking at high hardness levels. Its air hardening characteristics are also of much help, for, during braking, the surface metal may get hotter than 1700° F., and

the face of the brake rehardens on cooling. Nonmilitary applications, in addition to bolting, include elevator parts in catalytic cracking units in the petroleum industry, retractable soot blower tubes, and gears operating up to 1000° F.

This steel has a 1000-hr. rupture strength of 60,000 psi. at 1000° F. but this value falls to 20,000 psi. at 1100° F. A higher-vanadium modification called "17-22-A" V has the excellent 1000-hr. rupture strength of the order of 37,000 psi. at 1100° F. This grade is now under extensive test for possible use as turbine rotors and for the structural parts of gas turbine engines for aircraft.

Figure 3 compares the 1000-hr. rupture strengths of "17-22-A" S (and the one available value for "17-22-A" V) with four English steels which have been used extensively abroad.

HIGH-CHROMIUM STEELS

Considerable attention has been given to the development of 12% chromium steels capable of withstanding high stresses at 1100 to 1200° F. One of the best obtained to date is that designated as Rex 448, which, in addition to 11% Cr, contains Mo, V and Cb (See Table I). To obtain the maximum high-temperature strength, it must be quenched from 2100° F., and then tempered to the desired hardness. Figure 4 shows the 1000-hr. rupture strengths of this and some other variants with similar amounts of chromium. Lines for "17-22-A" S and DTD give a comparison with the lower-alloy steels. At 1100° F. Rex 448 is only slightly superior to the higher vanadium modification previously mentioned (designated as "17-22-A" V) but at 1200° F. its superiority is more pronounced. It is superior to all of the 12% types except H 46 in the 1100 to 1200° F. range. The latter contains columbium, and it would appear that columbium is essential in imparting the maximum high-temperature strength to this group of alloys.

However, certain of the more recent alloys of this type developed in America, containing no columbium, possess rupture strengths nearly as good as the English steels. Among these may be mentioned General Electric Co.'s Lapalloy, containing molybdenum and vanadium, and Crucible Steel Co. of America's Grade 422. The latter differs from the others in that it also contains tungsten, as can be seen from the analyses in Table I.

HIGHER ALLOYS

The more common grades of the chromium-nickel austenitic steels are widely used in the higher-

Table Ia – Nominal Composition of Selected Lower-Alloy Steels

Alloy	C	Mn	Si	Cr	Ni	Mo	Cb	V
1.25 Cr, Mo	0.10	0.50	0.75	1.25	–	0.50	–	–
2.25 Cr, 1 Mo	0.10	0.50	0.30	2.25	–	0.50	–	–
"17-22-A" S	0.30	0.60	0.75	1.25	–	0.50	–	0.25
"17-22-A" V	0.25	0.80	0.75	1.25	–	0.50	–	0.85
Rex 448	0.10	1.00	0.50	11.00	0.80	0.70	0.50	0.25
H46	0.15	0.35	0.40	11.00	–	0.60	0.15	0.75
422	0.20	0.80	0.50	13.00	0.75	1.00*	–	0.30
Lapalloy	0.30	1.00	0.50	11.50	–	2.75	–	0.25
12 Cr, Mo	0.15	1.00	1.00	11.50	–	3.00	–	–
12 Cr, Mo, Ni	0.15	1.00	1.00	11.50	1.50	3.00	–	–

Table Ib – Nominal Composition of Selected Higher Alloys

Alloy	C	Mn	Si	Cr	Ni	Mo	Co	Cb	Ti	Al
304	0.06	1.00	0.50	19.0	10.0	–	–	–	–	–
321	0.06	1.50	0.50	18.0	12.0	–	–	–	0.40	–
347	0.06	1.50	0.50	18.0	12.0	–	–	0.70	–	–
310	0.08	1.50	0.50	25.0	21.0	–	–	–	–	–
314	0.08	1.50	2.00	25.0	21.0	–	–	–	–	–
16-25-6	0.10†	1.35	0.70	16.0	25.0	6.00	–	–	–	–
A 286	0.05	1.35	0.95	15.0	26.0	1.25	–	–	1.95	0.20
Discaloy	0.05	1.35	1.00	13.5	26.0	4.00	–	–	1.60	0.10
S 816	0.40	1.50	0.70	20.0	20.0	4.00§	40.0	4.00	–	–
M 252	0.10	1.00	0.70	20.0	54.0	10.00	10.0	–	2.50	0.75
Waspalloy	0.05	0.70	0.40	19.0	58.0	3.00	15.0	–	2.50	1.20
Nimonic	0.10	1.00	1.50	19.0	50.0	–	20.0	–	2.40	1.20
Inconel X 550	0.05	2.00	0.70	15.0	73.0	–	–	1.00	2.30	1.20

* Plus 1% W † Plus 0.15% N_2 § Plus 4% W

pressure, higher-temperature applications, although the amount has recently been curtailed by governmental restrictions on nickel and columbium. In the steam power industry the stabilized grades find the greatest favor. Type 347 (18-12 Cb) is being used for main lines carrying steam at 1100° F., and Type 321 (18-12 Ti) for superheater tubes when the metal temperature is higher than 1050° F. Large quantities of Type 347, as well as 304 (19-10), are being used in plants being built for the U. S. Atomic Energy Commission. These alloys, as well as Type 310 (25-20), and its higher-silicon modification Type 314, are widely used in aircraft gas turbines as well as in the exhaust systems of piston type engines.

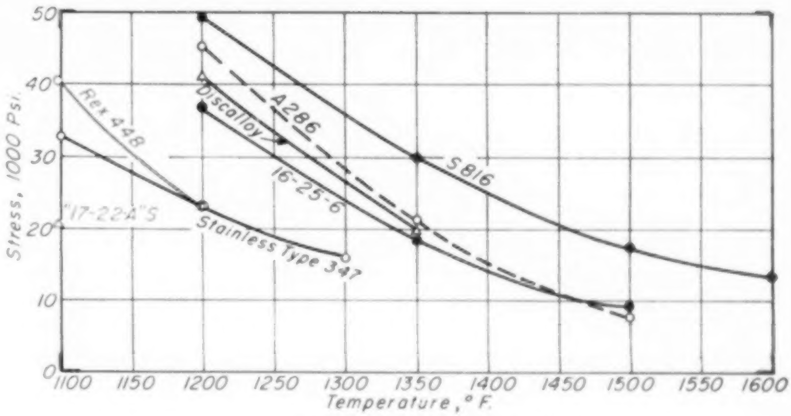
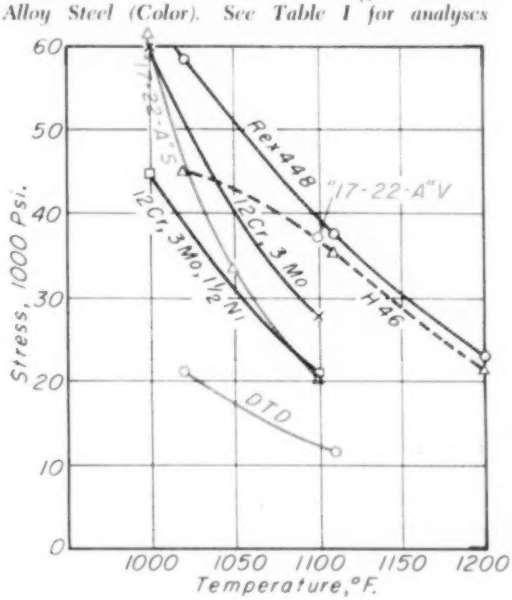


Fig. 5 – Comparative Stress-Rupture Tests for Various Higher Alloys Used for Gas Turbines. Data for two of the steels classed as "lower alloy" are in color

Still higher-alloyed austenitic alloys are the basic materials for many of the aircraft gas turbines. Most of the rotors are made of either the so-called "hot-cold worked" or the precipitation hardened alloys. An example of the first is 16-25-6 (Cr-Ni-Mo) and of the second group, A 286 and Discaloy. (Their compositions are included in Table I.) The "hot-cold worked" alloys have so far been favored by designers of gas turbines, but considerable interest is now being shown in the precipitation hardened alloys. The two steels of this latter type receiving the most attention for rotors, A 286 and Discaloy, both contain titanium as an essential alloying element. This may cause some difficulties in the melting and forging operations.

Fig. 4 – Stress-Rupture Tests at Various Temperatures for Steels Containing About 12% Cr (Black) With Two American and One English Lower-Alloy Steel (Color). See Table I for analyses



Turbine blading is one of the most critical parts of the gas turbine, the temperature being of the order of 1500° F. The materials commonly used are so highly alloyed that they may no longer be classified as "steels", steels being loosely considered as containing a minimum of 50% iron. The alloy most widely used has been S 816, although consideration has been given to many others such as the M 252 and Waspalloy listed in Table I.

The high-temperature properties of these higher alloys may vary greatly depending on processing conditions, heat treatment and many other factors. However, what are believed to be representative 1000-hr. rupture strength values are compared in Fig. 5. Type 347, as should be expected, possesses the lowest, and S 816, the highest rupture strength throughout the temperature range considered.

FUTURE TRENDS

There is still need for a chromium-nickel austenitic steel or alloy with greater high-temperature strength for the steam power and chemical industries. Steam temperatures of 1150 to 1200° F. with pressures of 4000 to 5000 psi. appear to be not far off. These will involve metal temperatures in the superheaters of the order of 1250 to 1300° F. Of the steels approved by the

Trends in Gas Turbine Alloys

A.S.M.E. Boiler Code, Type 316 appears to be the most suitable for such service, but even with the use of this analysis, tubes with very heavy wall will be required. Likewise in the chemical industry, some of the new coal hydrogenation processes require metals capable of operating under very high temperatures and high pressures.

The trend in gas turbines may follow either of two courses. If air cooled parts are more widely used, then the present alloys will be satisfactory; the over-all alloy content of the engine can even be reduced. On the other hand, if the trend continues toward ever-increasing temperatures, newer and better materials will have to be developed. Of the possibilities, the most promising appear to be the molybdenum-base alloys, the cobalt-base alloys and the nickel-base alloys. Certain of the "cermets" – ceramic-metal combinations – may also be capable of improvement to a point where they can be safely used in important high-temperature services.

Sulphurized Surfaces Resist Wear and Seizure

By BERNARD JOUSSET, President
Société Parisienne de Cémentation,
La Garenne-Colombes, France

CONSIDERABLE success has been achieved in France in recent years with relatively new methods of heat treatment. For example, I saw no better or more systematic use of the carbonitriding process in the United States, during my tour in 1951 with the first World Metallurgical Congress, than now is to be found in French automotive plants. Currently there are also under study and experimental application at the Renault plant in Billancourt special heating and quenching cycles designed to induce internal stresses in steel parts in such manner as to improve their fatigue characteristics.

Along this same line of progress it is appropriate to describe the production of superior wear resistance on cast iron and steel engine parts by a heat treatment which adds a considerable amount of sulphur to the surface, as performed by the Société Parisienne de Cémentation in its plant near Paris and by the Partiot Heat Treating Co. at Rueil, France. Wear resistance is notably increased although there is little or no increase in superficial hardness – a fact which further supports the idea that there is no close connection between hardness and wear resistance.

Two methods (and their combination) have been found to be quite successful. One uses, at 300° F., a water solution of sodium hydrate as a carrier for elemental sulphur. The other uses a mixture of neutral salts melting at 880° F., and carrying a proprietary "S" salt containing derivatives of sulphur (plus a "C" salt if a cyanide effect is also desired). The low-temperature process appears to be a French adaptation of an American proposal dating back to the early 1940's, Neely's "Surfide process", covered by U.S. patent No. 2,266,377*. The surface also appears to have lubricant adsorbing properties, similar to the well-known American process known as "Parco Lubrite". The low-temperature sulphurizing process has been extensively and successfully used in our shop.

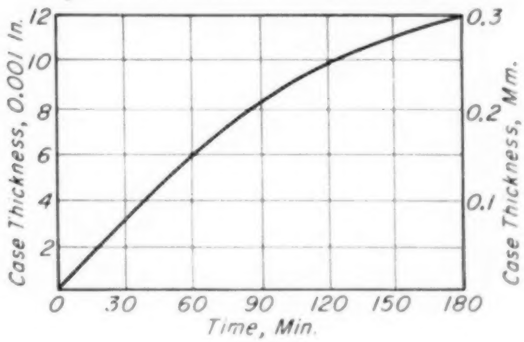
The salt bath or "Sulf-Inuz" treatment is promoted in France by the Société d'Applications

* A caustic sulphur treatment was described by J. E. Jackson in "Wear Resistant Castings of Diesel Engine Cylinders" published in *SAE Journal* in 1941.

des Traitements de Surface (usually abbreviated to S.A.T.S.), and by Prolin Products of Lausanne in Switzerland, Italy and Austria. Practically all of the data and results to be presented in this article will concern this higher-temperature heat treating process.

The nature of the surface layer produced on iron or steel after cementation by sulphur by either of the above processes, and the mechanism of the action, have not yet been properly studied – as far as is known to the present author. So the process will be called "sulphurizing", without implying anything about the state or combination of the sulphur (plus carbon and nitrogen) in the superficial layers. Depth of penetration can best be measured during microscopic examination of a sample cross sectioned and polished so there is little or no rounding of the edges. Such a sample is lightly etched with 1% picric acid (hot), and then immersed in a 25% solution of acetic acid until the sulphurized layer shows up as a darkened, fine-grained layer. Another etchant is a fresh solution of hydrogen peroxide in two parts of 10% sodium hydroxide.

Fig. 1 – Rate of Growth of Sulphurized Layer on Cast Iron in Salt Bath at 1060° F.

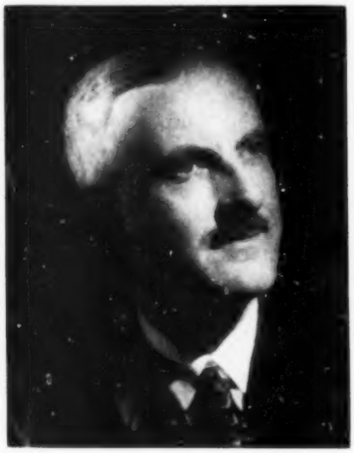


OPERATION OF THE BATH

Confining our attention now to the S.A.T.S. "Sulf-Inuz" process, it may be said that success will require careful control of the nature of the bath. Before each batch of work is immersed the analysis of the bath must be checked and "regenerated" if necessary. The temperature must be under close conti.:. (Melting point is 880° F.; operating temperature is 1060° F., plus or minus 20°.) Finally the bath should be kept under a cover to prevent rapid oxidation of the sulphur-containing additions.

Penetration of sulphur into the surface, under these optimum conditions, is a function of time, as shown by the curve, Fig. 1, although the maximum commercial thickness should be taken as 0.3 mm. or 0.012 in.

The Partiot plant has two pot furnaces devoted to this work. One is 12 in. in diameter by 16 in. deep; it is in a refractory pit heated with electric resistors, automatically controlled for temperature. This is suitable for small pieces. Larger parts, such as sleeves for diesel cylinders, are heated in a 24-in. pot placed in a gas-fired setting. Alongside is a suitable tank for simultaneous quenching and washing, containing hot water (175° F.). This equipment is served by a small



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overhead crane, and has necessary jigs, quenching baskets, and hooks. The laboratory also contains necessary equipment for quick analysis of the bath, and the wear testing machine to be described.

In three years of industrial experience much difficulty has been experienced with the salt pots. For the usual salt baths used for heat treating, a cast pot of 20% nickel, 20% chromium, 60% iron alloy is almost a standard in France. However, such a pot will be penetrated by the sulphurizing bath in about 300 hr.—in fact, any refractory alloy containing nickel seems to be corroded very rapidly.

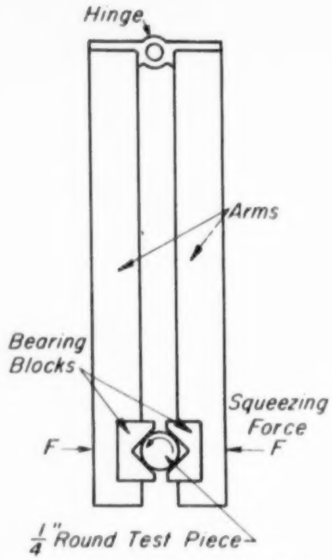


Fig. 2 – Diagram of Action of Wear Testing Machine

Partiot engineers next tried a pot of ordinary gray cast iron. It, however, did not withstand the repeated large temperature differences, day by day, either because of poor thermal fatigue or poor resistance to the expansion and contraction of the salt when melting and solidifying.

Finally, they constructed a pot of ordinary mild steel plate, ⅜ in. thick, rolled into a shell 24 in. diameter and 36 in. long. The longitudinal seam was arc welded. A domed end was then welded to the bottom. Finally the exterior was metallized (sprayed) with aluminum. This pot, in a gas-fired setting, has now given two years of service. Corrosion at the salt line, as well as undue oxidation of the bath, is prevented by a fairly closely fitting cover, divided on its diameter for easy access and to clear the equipment for handling the parts being heat treated.

It has been suggested that such a bath could well be heated by resistance of current between immersed electrodes, as has been so successful in other salt baths, but no experience was had with this. It might give the necessary stirring action which is now provided by a horizontal arm, fixed to the bottom of a vertical bar. The latter is geared to a slow-speed motor in such a way that the submerged arm is waved to and fro about 30 times a minute. The arm is near the bottom of the pot; its vertical bar is near the side; thus the system does not interfere with work in process.

Another system used at Compagnie Générale de Moteurs for sulphurizing iron linings for diesel engines consists of a device for moving up and down the metallic basket containing 30 linings. A reciprocator placed near the roof maneuvers the chain by which the basket is suspended. The run is 8 in. and the frequency 30 sec.

Thanks to these various devices, the variation in temperature from one side of the bath to the other never is more than plus or minus 10° F., the maximum for good results.

SIZE CHANGES AND COSTS

A slight increase in size accompanies sulphurizing. We do not know of any way of computing this, but it amounts to no more than 0.01 mm. (half a thousandth of an inch) on the diameter of the largest pieces that we have heated. Another more important point is that the very surface is inclined to pulverize up to that same depth, and it is only underneath that a properly treated surface is found. This powdery surface is not dangerous, because the piece as withdrawn from the salt bath is covered with solidified salts. Cleaning is therefore indispensable, and it is best to follow this with a soft wire brush. Many sulphurized parts can then be assembled into their intended mechanisms and can be "run in" immediately. Only for the most precise specifications is it necessary to grind, hone, or otherwise finish the sulphurized surface. In those instances it is necessary to make a grinding allowance of 0.001 in. on original diameters, and of course to sulphurize 3 hr. to maximum commercial depth so the wear resistant surface will not be too deeply removed by this final finish. Otherwise sulphurizing to a depth of 0.15 mm. (0.006 in.), requiring 1-hr. heat treatment, may be considered adequate.

With the above facts in mind, the mode of operation is as follows:

1. Preheat the completely machined part to 850° F. to avoid damage by heat shock and also to prevent the temperature from dropping unduly in the bath.

2. Immerse in the molten "S.A.T.S." bath, superheated to 1060° F. for 1 to 3 hr., depending on the case thickness desired.

3. Quench the work in hot water (175° F.). A stay of 20 min. is usually sufficient to dissolve the adhering salt.

Results of Wear Tests

4. Clean the fine powdery surface with a soft metallic brush.

5. Finish machine, grind or hone (or run in) if specified.

6. Cover with a rust-protective oil. The part then is a brilliant black.

Since these operations parallel well-known and conventional heat treatment practices, the costs may be readily computed for conditions existing in individual shops. One thing to remember is that the sulphurizing bath, at temperature, is rather viscous, and "drag out" is therefore about double that if the part were merely cyanided.

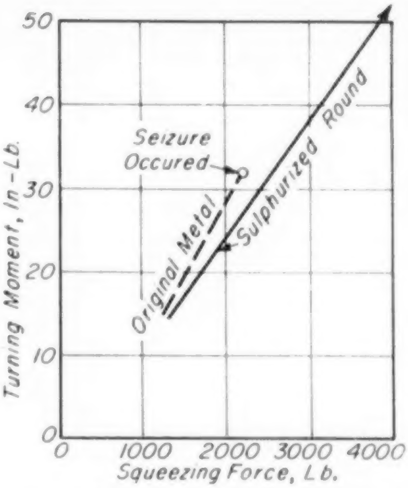


Fig. 3 – Turning Moment Versus Squeezing Force on Round Test Pieces, Sulphurized and Not Sulphurized. The sulphurized test piece did not seize the bearing blocks even at the highest pressure attainable

Care of Bath – The salt bath is very active and requires frequent adjustment as to constitution. The carrier is a eutectic mixture of neutral salts of low melting point. The active part is made up of a salt comprising a molecule of incompletely oxidized sulphur; another component is also added to catalyze the reduction to sulphur that takes place at the active surface of the steel part.

This leads to a neutral carrier plus sulphite or hyposulphite of sodium plus sodium cyanide. Conservation and economy demand measures to slow down the oxidation of the cyanide to cyanate and carbonate. As the cyanide is transformed, the melting point of the mixture tends to increase as well as its viscosity at operating temperature. Furthermore the sulphur compounds in the bath become unstable. Hence the necessity of close cover over the fluid salt and periodic analysis – at least twice daily. A sample is taken by plunging a cold iron rod momentarily to the bottom of the pot; it comes out covered with a thin layer of solidified salts. All this is broken off, and part of it is pulverized in a mortar prior to analysis by simple and rapid methods outlined by the S. A. T. S. firm. Cyano compounds (cyanide) should be more than 8%; sulphur compounds should be more than 0.25%. Otherwise appropriate amounts of "C" and "S" salts are to be added to the bath for its regeneration. Small tell-tale samples (or ¼-in. rounds suitable for the wear testing machine) should be included in each run and the depth of sulphurized layer determined either microscopically on a polished and etched cross section or by a sulphur print in contact with silver bromide photographic paper according to Baumann's well-known method.*

WEAR TESTING MACHINE

A successful wear testing machine is the American-made Faville-Levally Wear Tester, whose essential portion is shown in Fig. 2. V-shaped bearing blocks are fitted into the ends of a pair of bars so arranged that they may be pressed together. These bear on a short ¼-in. round made of the steel or iron being heat treated, which has accompanied a given batch through the process. This short round is chucked into a driving mechanism; the arms are pressed closer and closer together by steadily increasing force, up to 4000 lb. max., and the energy required to turn the test piece is registered by a dynamometer. No lubricant is used, and the squeezing force is increased to the limit of the machine or until seizure occurs and the test piece shears a 3-mm. brass pin in the chuck. Duplicate tests are run on test bars, not sulphurized; a representative plot is shown in Fig. 3. Wear may also be estimated by loss of weight of test pieces after standard time of running at maximum jaw pressure. For example, three pieces were cut from the same bar of cold drawn shafting, and run in this machine for 60 min. at maximum pressure (4000 lb.). The untreated bar lost 750 mg. weight; the second portion case hardened lost 250 mg.; the third portion sulphurized lost 19 mg.

The bearing blocks are of hardened toolsteel. For the more important work it would be preferable to make them (as the test piece) of the material being treated and sulphurize them in the commercial way. Some irregularities in the test have also been avoided by doubling the diameter of the sulphurized round and appropriately enlarging the bearing blocks.

* See Footnote B, p. 391, Metals Handbook, 1948 Edition.

Sulphurizing Engine Parts and Tools

It is our belief that wear may be minimized on steel or cast iron machine parts, subject to friction either hot or cold, if such surfaces are sulphurized as indicated above. Cylinder liners, piston rings, tools and forming dies are typical.

Much success has been had in treating parts of motors which are using too much engine oil. Such engines ordinarily show this defect fairly early in their life – for example, after the vehicle has traveled no more than 12,000 to 15,000 miles. When the cylinder liner, pistons and piston pins are sulphurized, such a motor after reassembly will consume an insignificant quantity of oil. One such, disassembled after 65,000 miles, showed no wear line at the top of the piston travel and less than 0.06 mm. (0.002 in.) on cylinder diameter.

Experience of a number of firms, operating diesel engines in very severe service, substantiates the above facts.*

Information has been published on a comparative test wherein one engine was equipped with alloy cast iron (nickel-chromium) liners untreated, while a duplicate engine had sulphurized cylinder liners. After a 2-hr. bench test, these engines were dismantled. Wear on the conventional liners averaged 0.32 mm.; on the sulphurized liners it was 0.02 mm. This indicates that the latter "run in" very rapidly–in fact 100 km. (60 miles) is all that is recommended for run-in of such engines.

During reassembly the liners on these engines were then divided, so that each engine had part of one kind and part of another. After 500 hr. of normal operation they were again dismantled and cylinder diameters accurately gaged. Average wear on the untreated linings was 0.08 mm.; on the sulphurized linings 0.025 mm. One subsidiary advantage of sulphurizing cylinder linings and then honing to size is that the long soaking removes internal strains and gives a sleeve of very stable dimensions.

One "trick" experiment may be cited on an agricultural tractor wherein the ball bearings on the main drive shaft were replaced with smooth cast iron journals, sulphurized, and the appropriate areas on the shaft were also sulphurized. This tractor was operated for 5 hr. at an average speed of 10 miles per hr. The bearings did not seize, even though they were run dry and heated slightly.

Some tests on sulphurized tools are interesting. When drilling 4-mm. holes in leaf springs, heat treated to 170,000 psi. tensile strength (C-34 hard), a well-known drill of American make drilled 20 mm. in unit time; a fine Swiss drill was able to go 22 mm.; the latter, after sulphurizing, drilled 34 mm. in unit time. Expressed in break-down *time*, the high speed steel drill, after sulphurizing, will maintain its edge under standard drilling conditions nearly three times as long as ordinarily. It is possible that some of this increased life is due to the more complete transformation of residual austenite in the high speed steel during the long stay in the sulphurizing bath at 1075° F.; likewise, some may be due to the nitrogen absorbed from the cyanide in the bath.

ADVANTAGES AND LIMITATIONS

Sulphurizing, which gives a deep, porous layer without superficial hardness (possibly self-lubricating on a cast iron surface from free particles of graphite) is recommended to resist friction, and has the following advantages:

1. Economy in choice of steel and cast irons.
2. Sometimes eliminates the necessity for case hardening or nitriding.
3. Easy final machining, because of absence of intensely hard microconstituents.
4. Less wear on rubbing surfaces.
5. No deformation due to residual stresses.
6. Lower cost, not so much for the treatment itself, as for the finished piece.

The prime limitation of the process is that it is not adaptable to steel pieces which have been quenched and tempered to correct tensile strength or to carburized and quenched parts. The bath is so hot it overtempers and softens the part. Even this, however, may be avoided by the low-temperature sulphurizing treatment mentioned early in this article which utilizes a caustic solution at 300° F. – *provided* the nitrogen added to the surface in the salt bath treatment is not needed. In our own practice we find many places where the low-temperature process is quite adequate and gives a desirable added durability to heat treated steel parts.

In summary: Sulphurizing may be done either at moderately high or at quite low temperatures. It is suitable for cast iron, steel or alloy iron or steel, either in heat treated or in annealed condition. It produces a surface of extraordinary wear resistance and one which "runs in" in a very short time. The surface accepts and retains lubricants excellently and resists seizure even when dry.

* Diesel motors for large trucks whose rings and liners are sulphurized commonly consume no more than 1.5 liters of oil per 1000 kw. of vehicle travel (1 pint per 200 miles), even after a total mileage of 75,000.

Norwegian Production of Stainless Steels

By JOHN SISSENER, President
Norwegian Foundrymen's Technical Assoc.
Oslo, Norway

STAINLESS STEEL has been made in Norway since 1916 in electric furnaces from steel scrap and ferrochromium. First production was at Stavanger Electro-Staalverk, on the west coast of Norway – a heat of 14% chromium steel. This firm still rolls bars and strip, although other Norwegian producers are foundrymen.

The American reader may be interested to learn that the molding sand used for stainless steel castings is now exclusively olivine sand. This practice has been described in a number of articles in American papers.

Olivine is a magnesium silicate (Mg_2SiO_4) contaminated with iron oxide. It is found massive, is mined and crushed and delivered as such to the foundries. The usual binder is bentonite clay, well known to American foundrymen. Olivine molds give a very good surface to all the stainless steel castings, being quite refractory at the casting temperatures of the stainless steels.

STAVANGER ELECTRO-STAALVERK

Stavanger Electro-Staalverk A/S was founded in 1910 with the prime purpose of melting and refining scrap steel from the southwestern coastal area. The works are situated at Joerpeland, about 10 miles across the fjord to the east of Stavanger, where a waterfall supplies hydroelectric power for the works and for the community.

From the start the works have concentrated on making highly alloyed constructional and toolsteels in forged and hot rolled condition. Production started in 1913 and, as mentioned above, the first stainless 14% chromium heat was poured in 1916. From then on the production of stainless steels has been one of Stavanger's specialties.

Since the last war the works have been expanded and several new departments have been added – notably a cold rolling department, a permanent magnet plant and equipment for making sintered carbide parts. At the present time the company employs approximately 850 workers.

Since Stavanger Electro-Staalverk is the only steel works in Norway making alloyed steel in cast, forged, hot or cold rolled condition, its production is very diversified and characterized

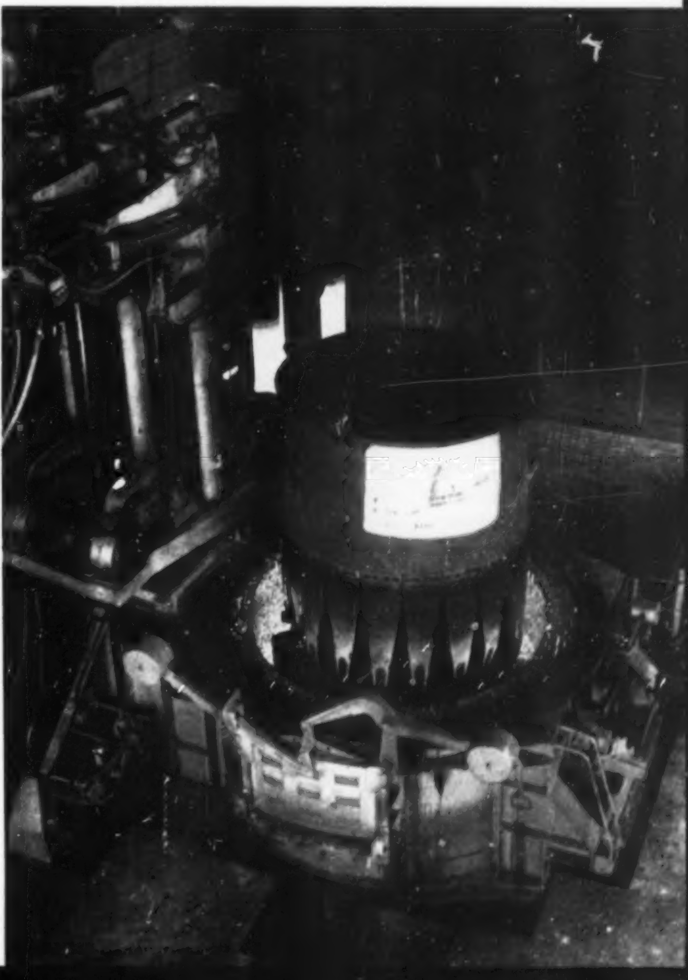


Fig. 1 – Charging Bucket With Orange Peel Bottom Dropping Scrap Into 12-Ton Heroult Furnace. (Courtesy Stavanger Electro-Staalverk)

Fig. 2 – Reheating Furnaces in Stainless Steel Dept. at Stavanger, Showing 1-Ton Forging Manipulator

is used where corrosion is moderate and some wear resistance is necessary, as in paper mill knives (Hollandar knives). This grade is used heat treated in hardness levels up to about Rockwell C-50.

An analysis similar to A.I.S.I. Type 431 but with higher chromium – nominal analysis 0.14% C, 19% Cr, 1.5% Ni – is a martensitic-austenitic grade normally forged and heat treated to tensile strength of 110,000 to 130,000 psi. It has been made into pump and valve shafts and spindles as well as propeller shafts for small vessels. It satisfactorily resists sea-water corrosion when submerged. It is seldom supplied in the form of castings.

The fourth somewhat unusual

by small lots. Total tonnage is small in comparison with American steel works making carbon steels but is comparable to the average toolsteel plant.

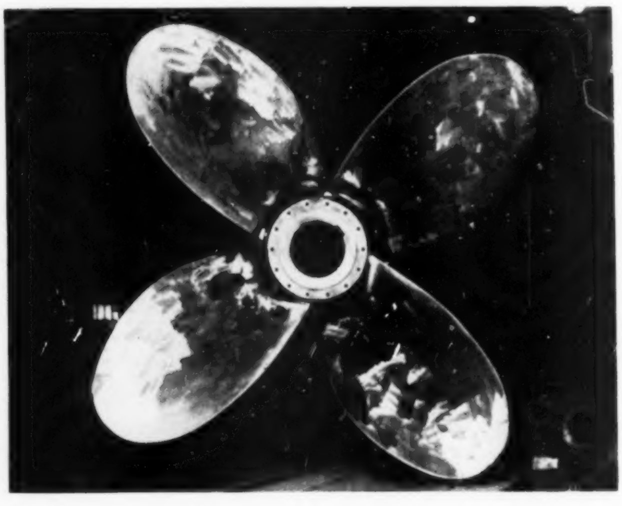
Library facilities in Norway are especially good in foreign technical books and periodicals. American technical literature is especially widely read. It is not surprising, therefore, that the development and manufacture of alloyed steels have followed closely the trend abroad. Most stainless steels of A.I.S.I. specifications are manufactured in Norway, on demand, with the exception of the extra-low-carbon austenitic grades and those free-machining grades containing selenium. On the other hand, a few grades not listed by the American Iron and Steel Institute are made, and some grades listed but apparently not extensively used are quite common in Norway. Four analyses may be mentioned.

A medium-carbon chromium-molybdenum steel (nominal composition 0.12% C, 14% Cr, 1.1% Mo) which can meet more severe corrosive attack than the ordinary 14% chromium grades. It has been successfully used for pump, impeller and valve bodies and shafts for high pressure and temperatures up to about 850° F.

A higher-carbon steel somewhat similar to the above (nominal composition 0.30% C, 14% Cr, 0.8% Mo)

analysis finds a parallel in America in Type 329, although the Norwegian version is low in carbon with nickel and molybdenum on the high side of the range. Its nominal composition is 0.08% C, 27% Cr, 4.5% Ni, 1.5% Mo. This is a ferritic-austenitic grade which is used extensively instead of 18-8-Mo grades (TS 316), for further conservation of scarce nickel. It has excellent casting properties and has been supplied to the chemical industry in the form of pumps and valves – as for instance for sulphite cellulose equipment. Sometimes plungers are precipitation hardened by sigma phase formation

Fig. 3 – Fifteen-Ton Propeller, One of Ten Furnished Recently to an English Shipbuilder by A/S Strömmens Vaerksted



to prevent galling against valve bodies.

Although the extra-low-carbon austenitic grades recently promoted in the United States are not manufactured in Norway, our aim has always been to supply these austenitic alloys with as low carbon as possible rather than making the so-called stabilized grades. The grades corresponding to A.I.S.I. Types 304 and 316 are normally supplied with a maximum carbon content of 0.05 to 0.07% instead of the 0.08 and 0.10% respectively in American production. Ferrochromium is available in Norway which will enable us to make even lower-carbon stainless grades, but so far the poor yield – caused by difficulties in forging and hot rolling – has prevented their commercial exploitation. The same difficulties have hampered the development of manganese-chromium austenitic grades, although some are successfully made that contain up to 5% nickel.

Since the last war the working of stainless heats with oxygen has been introduced. The best procedure found is to charge about 60% stainless scrap and the rest ordinary steel scrap. The chromium recovery averages 85 to 90%.

Research at Stavanger has endeavored to discover steel analyses and methods of manufacture which will consistently give a high yield, ingot to marketable shapes. To this aim the hydrogen content, the role of different deoxidizers and degasifiers, and the effect of ferrite in the austenitic grades have been given careful consideration. Since the American discovery of the beneficial effect of cerium, lanthanum and related metals on forgeability, additional study has been devoted to the problems of deoxidation, denitrogenation and dehydrogenation, when using the more conventional alloys for this purpose.

Fig. 4 – Fairly Massive Pump Parts Molded in Olivine Sand and Cast in Low-Carbon 27% Cr Stainless Steel by A/S Myrens Verksted of Oslo, Norway

FOUNDRY PRACTICE*

A/S Strömmens Vaerksted was founded in 1873 as a plant making railroad cars. In 1902 a steel foundry was added and by 1903 it was approved by Lloyds Register of Shipping as the first steel foundry in Scandinavia.

From 1902 up to 1925 the steel was made in Tropenas converters, but from 1925 on, Heroult basic electric furnaces have been used. Today two electric furnaces of 40 and 50 tons respectively are in operation. The works employ around 850 people, about half of them working in the steel foundry.

Although the works are located in the countryside 12 miles from Oslo, steel castings for the shipbuilding industry have for years been the most important part of the production. Steel castings for the turbine industry also are playing an increasingly important role. A/S Strömmens Vaerksted can deliver castings with a finished weight up to 50 tons. The foundry has its own machine shops capable of finishing even the largest stern frame castings for the shipbuilding industry.

Production is under rigid control in modern chemical and metallurgical laboratories. Crack detectors are in extensive use; turbine castings are usually X-rayed.

The foundry is equipped with three heating furnaces of appropriate size, two of which are electrically heated. These are of Strömmens own design. All stainless steel castings are annealed in the electric furnaces, where an exceptionally uniform heat treatment is secured; temperature variations are under full control.

Stainless castings made at Strömmens have the following composition: 13% chromium, 0.15% max. carbon, 0.45% silicon, 0.60% manganese, 0.02% max. phosphorus, and 0.015% max sulphur.

Thanks to years of consistent effort Strömmens Vaerksted has managed to bring the mechanical properties of its castings up to a consistent high level. Especial attention has been given to toughness and ductility. The following

(Continued on p. 164)

*The information for the preceding section on the Stavanger plant was kindly furnished by Alf Pettersen, chief metallurgist. The data on the Strömmens practice was obtained from Alf Ihlen, president of the company.

Advanced Practices in Italy

FIAT is probably best known outside of Italy as a manufacturer of fine motor cars. This was indeed its first aim when organized in 1899, as shown by the full name of the company—Fabbrica Italiana Automobili Torino. In the intervening half century it has expanded into one of the largest European industrial groups. As shown by the organization chart, Fig. 1 below, it manufactures many lines of machinery and equipment driven by internal combustion engines – motor vehicles, trucks, tractors, trolley buses, large diesel engines, aviation engines and aircraft, as well as rail and tramway materials. Its entire employment roll totals about 70,000, distributed among 18 major works.

In this issue of *Metal Progress* reviewing world metallurgy it is thought fitting to describe some units of this group. Admittedly they will be the most recent in date and most advanced as to their engineering and operating characteristics. Nevertheless, it is possible in this way to indicate that we are alive to the possibilities of mass production and are utilizing some of the latest and best equipment and methods and also that Italy can boast of an important, in-

Fig. 1 – Organization Chart of FIAT

By ALBERTO OREFFICE, Chief Engineer
Central Research Laboratory
FIAT, Turin, Italy

tegrated organization, comparable to similar concerns in America. In fact, FIAT is possibly unique in that its properties extend clear back into the ownership of mines for raw materials, hydro-electric plants for power, and gas wells for fuel. This "vertical" character of the organization has resulted from the industrial conditions (or perhaps it would better be said, the *lack* of varied industry) in Italy during its formative years. It was necessary to insure adequate supplies at every stage of manufacture. Thus, FIAT produces most of the steels and nonferrous alloy (as bars, shapes, pipe, sheet) necessary for its operation as well as a surplus of some items for sale to others; its special cast iron and light alloy foundries supply the castings; another factory furnishes all the springs required; most of the bolts, nuts, and fasteners are made within the FIAT group.

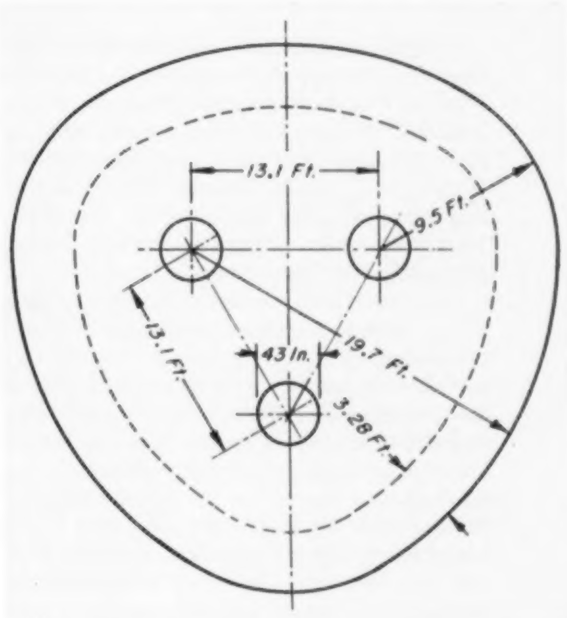


Fig. 3 – Cross Section of Tysland-Hole Electric Furnace for Smelting Iron Ore. Height from shell bottom to charge top is 17.4 ft. Refractory lining of hearth is 4.8 ft. thick

ELECTRIC IRON SMELTING

FIAT'S steel works section ("Ferriere") is in Turin and occupies a closely built area of 150 acres. Its annual production has steadily increased from 220,000 short tons of ingot in 1948 to 380,000 tons in 1953. Most of the steel is refined in gas or oil-fired openhearths of which there are three of 120-ton capacity (average daily output 280 tons each) and three of 55-ton capacity (average daily output 180 tons each). Finishing departments include bar mills, seamless tube mill, 72-in. sheet mill and wide strip mill. These mills are equipped with modern auxiliaries, many of them supplied by American firms. For example, Fig. 2 shows the continuous pickling line for sheet and wide strip in coils. An interesting feature of the precision mill (continuous) for rolling of bars is the large number of stands with vertical rolls whose function is to avoid any twist in the metal in process. For example the roughing set consists of three horizontal stands and three vertical ones, the intermediate set contains eight horizontal stands and four vertical, and the finishing mill contains three horizontal and three vertical stands. As an indication of its performance it can be said that it can take 2½-in. square billets and produce 0.20-in. round rod at 66 ft. per sec. (7.5 tons per hr.) to a dimensional tolerance of ±0.004 in.

Fig. 2 – Continuous Pickling Line for Sheet and Wide Strip in Coils, Moving at 200 Ft. per Min.

Steelmaking in Italy

Possibly an American visitor would be most interested in our two electric furnaces for smelting iron ore to pig iron. They are of Tysland-Hole design, which has been described by P. E. Cavanagh in *Metal Progress* for May 1950 (p. 631) in his article "Alternative Iron Smelting Processes". The furnace (Fig. 3) uses three vertical electrodes of the continuously formed, self-baking type (Soderberg).

Three 4000-kva. transformers, one for each phase, furnish power for each of these furnaces. One advantage is that the furnaces operate very well over a wide range of electrical input, so they can remain in operation over periods, long or short, of low power supply. Some 13,000,000 kw-hr. of power is put into these furnaces during the high-water season in the summer and this is responsible for some 5500 extra tons of pig iron. Charge is principally sinter cake, made of iron ore from our own mine at Traversella, pyrite cinder bought from the sulphuric acid industry, mill scale and furnace dust. Lump ore, high-manganese slag from the openhearths, and fine coke are also used as the charge.

Electrical power amounts to 2400 kw-hr. per short ton of pig iron produced; 22 lb. of the electrode mixture (carbon) is also consumed. Pig iron production per furnace on full power is 120 tons per day. Byproducts are 1320 lb. of granulated slag for cement manufacture and 2185 cu. ft. of top gas of 270 Btu. calorific power.

It is obvious that, in addition to our own pig iron production, large tonnages must be imported to supplement available scrap to supply our steel plant with raw materials.

ELECTRIC STEEL

Performance in our electric steel department, making toolsteels and alloy steels only, may be compared with similar American plants by using the following figures.

We have three American Lectromelt furnaces of 65-ton capacity. Fed by 18,750-kva. transformers, these will make, on the average, 210 tons of steel each per day. Electrodes are automatically regulated with an "amplidyne" system. These furnaces have movable roofs and are charged with drop buckets having retractable spherical or orange-peel bottoms to minimize the height of fall of the cold charge onto the hot furnace bottom. Electrode consumption is 13.25 lb. per net ton of steel melted and refined; power consumption 550 kw-hr.

Fig. 4 – Electric Furnace Bay in Turin Iron Foundry. At left center is one of the refining furnaces receiving a charge of molten metal (melted in another arc furnace further down the bay). In right foreground is a holding furnace (induction) pouring metal into a bull ladle in the pit below. Note funnel for adding graphitizing compound. Molding and casting bays are at right of this aisle

We have in this department also three Italian FIAT electric furnaces of 25-ton capacity, which produce 90 tons of alloy steel each per day. Each is fed by 5000-kva. transformers; electrode regulation is by electro-hydraulic systems. Electrode consumption is 15.4 lb. per net ton of steel refined; power consumption is 750 kw-hr. Furnaces have fixed top and hence are charged through the door by a conventional charging machine. It is also interesting to note that the walls of these furnaces are made of 16 prefabricated blocks of dolomite – a patented system.

Practically all of the ingots from this department are broken down by forging. Two presses of 350 and 800-ton capacity are in-

stalled for this purpose. Some of the billets are further worked on a battery of steam hammers. Adequate reheating and annealing furnaces serve this equipment.

CONTINUOUS IRON FOUNDRY AT TURIN

Americans will also be interested in the electric melting equipment newly installed in FIAT's modernized iron foundry in Turin, since I believe it represents a trend away from cupola melting that will be noticed more and more in the relatively near future—at least in regions where good coke is expensive or in foundries which make a considerable amount of alloy iron or low-sulphur iron for direct malleable.

The equipment shown in Fig. 4 is using a triplex process, namely, (*a*) melting the charge in the direct-arc furnace, (*b*) transferring the molten iron into other arc furnaces for adjusting to the desired chemical composition and temperature, and (*c*) transferring this refined iron to holding furnaces, which are low-frequency induction furnaces.

Specifically, melting is done in three 16-ton furnaces, rated at 4500 kva. Step *(b)*, refining, composition adjusting and overheating, is done in two 13-ton furnaces, rated at 2500 kva. each. Holding furnaces are four in number, rated at 180 kva., and hold 6.5 tons each. Holding furnaces pour into bull ladles in pits as shown at the right of Fig. 4, supplying by overhead trolley four molding and pouring lines.

Of these, one line pours about 30 large flasks per hr. Another is for cylinder blocks—70 per hr. The third is reserved for medium-sized castings; about 160 flasks are poured per hr. The last makes about 180 small castings per hr.

Advantages of the triplex melting equipment for the iron foundry are at least six in number:

1. Savings in coke (an imported combustible) while the electric power is home produced.

2. Use of charge material the composition of which is not exactly known.

3. Use of iron turnings coming from our own operations.

4. Ability to analyze, with the quantometer and spectrograph, the iron before pouring, thus giving us accurate and rapid control.

5. Production of cast iron, when desired, almost free from sulphur and well deoxidized.

6. Ability to pour castings at temperatures lower than that of the cupola iron, owing to the greater fluidity of the iron produced in the electric furnace.

Our installation at the Turin foundry can make each day 110 tons of castings of plain, malleable and special cast iron. In addition, other departments make 32 tons of castings of nonferrous alloy, poured in chill molds, in sand, or in dies.

CONTROL AND RESEARCH LABORATORIES

In addition to well-equipped control laboratories at each of the FIAT works, a central laboratory for testing and research was established long ago in Turin. At present the work in this laboratory is divided into five departments, as follows:

Metallurgy, which investigates problems in heat treatment and metal structure. Much work is done toward the improvement of the mechan-

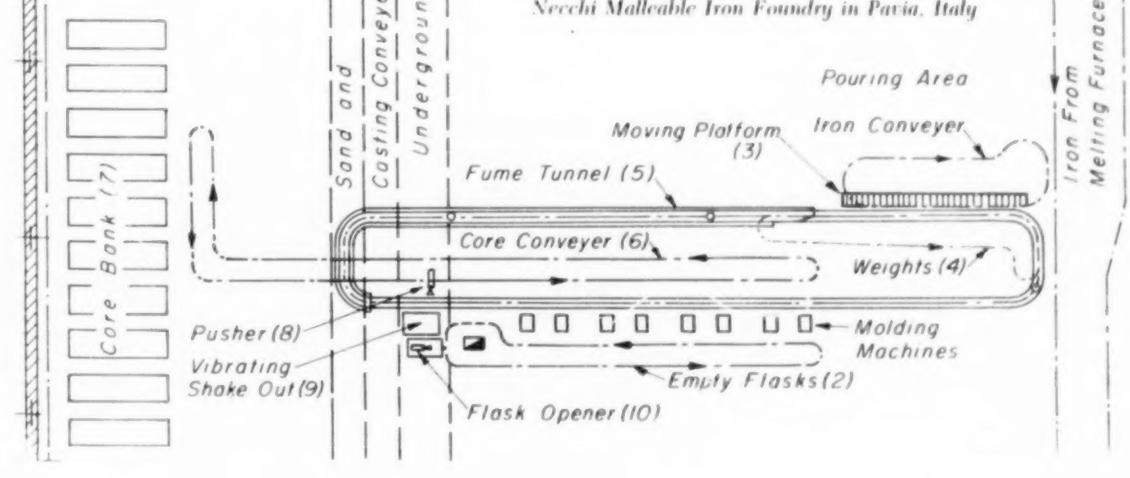


Fig. 5—Plan of Molding and Casting Line for 550 Flasks, 12½x12½x8 in., per Hr. at the Necchi Malleable Iron Foundry in Pavia, Italy

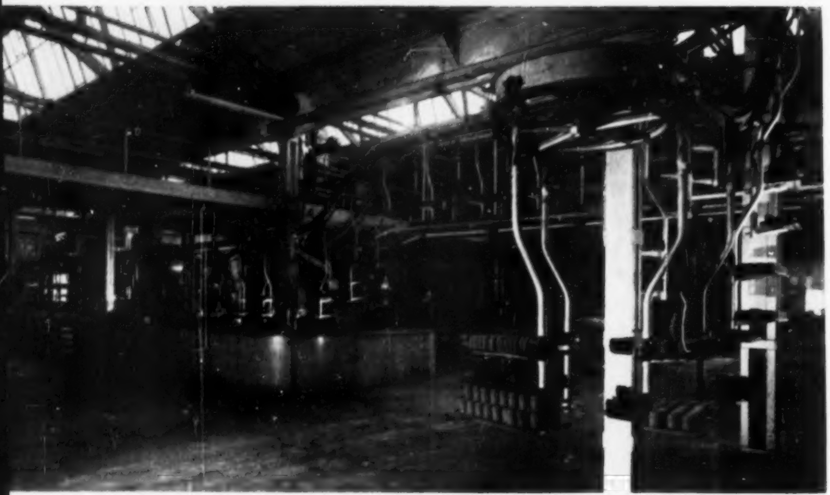


Fig. 6 – Molding Line at Necchi Malleable Foundry. Core conveyor at right. In middle distance is the fume tunnel

ical properties of metals and alloys, both ferrous and nonferrous. Corrosion testing is also done in the metallurgical department.

Chemistry, which has extensive equipment for work in inorganic chemistry, organic chemistry, and electrochemistry.

Electrical, which investigates electronic and electrical apparatus, not only for plant use but for installation in our product – especially in motorcars and aircraft. Vibration studies and stress analysis also fall within the electrical research department.

Physics and mechanics has the duty of studying metals by fatigue testing, and by X-ray radiography and diffraction. Heat resistance, wear resistance, and machinability are within the province of this department.

The technological department studies paints, rubber, plastics and sintered materials.

A broad modernization program, based on the latest experience in the foundry field, was started in 1948 and is now mostly completed in the Necchi Foundries at Pavia, a short distance south of Milan. Its purpose may be stated as (*a*) improvement of production, both quantitatively and qualitatively, and (*b*) improvement of working conditions.

Among the various new departments perhaps the most noteworthy is a new continuous cycle molding line, whose design and construction resulted from joint studies by Necchi's technical department and its methods office. Furthermore, important contributions have been made to the initial layout by an American M.S.A. Commission of foundry experts.

NECCHI MALLEABLE FOUNDRY

This molding and casting line, as may be seen from Fig. 5 on p. 87, comprises:

1. The molding area, consisting of four pairs of high-speed molding machines of the vibro-compression type in combined phase, pedal controlled. This is shown in the plan, Fig. 5. Each pair of machines makes a complete unit. Both coring-up and closing the drag and cope are done on the conveyer trucks in a predetermined position for each group of machines. The cores are distributed inside the main conveyer line continuously by means of an endless overhead conveyer, noted at (6) on Fig. 5 and photographed in Fig. 6.

2. The pouring area (Fig. 7) is equipped with a continuous automatic loader for weighing the molds. The workman who pours the molds stands on a belt having a speed equal to that of the conveyer's trucks – 13 ft. per min. – so that his position is fixed relative to the molds during pouring. In the plan these operations are shown at (3) and (4) of Fig. 5.

3. Fumes are under control by passing the molds; immediately after pouring, into a long tunnel, (5) in Fig. 5. Exhaust fans discharge fume and smoke to the outside of the building.

(Continued on p. 136)

Fig. 7 – Molding Line at Opposite End From Fig. 6. Molders and core setters at left middle distance; automatic weight handlers in foreground; workman pouring molds at extreme right stands on moving platform

Weldability of Steel as It Is Considered by Swiss Engineers

By CHARLES G. KEEL, Director
Swiss Acetylene Society
Basel, Switzerland

All readers of *Metal Progress* know the small Alpine country in the heart of Europe, Switzerland, as a manufacturer of high-precision watches and of good cheese. Probably not nearly as many of them know that Switzerland has also several large manufacturers of welded structures and possesses many outstanding examples of welded construction. "Weldability" of steel is consequently a problem of great importance to Swiss engineers. Particularly so, since we must import much of the steel we fabricate and the orders are generally of such small size that we cannot demand special analyses or steelmaking practices. In the following article I want to point out – by citing some examples – the principles we use to judge this matter of "weldability". Before I begin, it must be said that there have existed no standards and specifications having general acceptance in Europe. Our work in Switzerland is therefore guided by experience, by the results of modern research, and by the greatest care during manufacturing and inspection.

SWISS SPECIFICATIONS

The only Swiss specification dealing with the weldability of steel was issued in 1942 (Normblatt VSM 14042). It defines four grades of weldability, that is, (*a*) good, (*b*) sufficient, (*c*) bad, and (*d*) nonweldable.

A steel has "good" weldability if it is possible to weld it with conventional equipment and techniques at ambient temperature above 40° F. in plate or section thicknesses less than 1.6 in. and without thermal treatment, making a joint which has neither cracks nor hardened zones.

A steel has "sufficient" weldability if it is necessary to use thermal treatment and special precautions on plate thicknesses over 0.8 in.

A steel has "bad" weldability if all thicknesses require thermal treatment and special precautions in techniques or equipment.

A steel is "nonweldable" if one cannot surely make a weld in it which has neither cracks, hardened zones or other defects even when using special precautions and heat treatment before and after the welding process.

All our other standards issued after 1942, such as standards for welded steel structures, bridges, hydro-electric power plants, boilers, piping and machines, do not contain the term "weldability" and make no effort to define this unnamed property. This is quite easy to understand since the experts have not yet agreed. Does it mean susceptibility to cracks? or to brittle fracture? or to difficult handling? or to all taken together?

Probably the most commonly held view is that "weldability" is an inclusive term meaning an aggregation of properties, but the widest divergence exists as to what properties should be measured, how they should be measured, and the relative importance each to each.

For judging sensitivity to cracks in the heat-affected zone, chemical analysis and hardness measurements seem to be suitable. For judging tendency toward brittle fracture, various notched-bar impact tests are used, depending on plate thickness and steel refining practice. X-ray examination of welds is probably the most reliable judge of the technological properties of the electrodes – especially their tendency toward porosity.

Since all Swiss specifications for sheet include instructions for the conventional tests such as tensile strength, elongation, yield point, reduction of area, bending coefficient, these tests are made on steels purchased for welded struc-

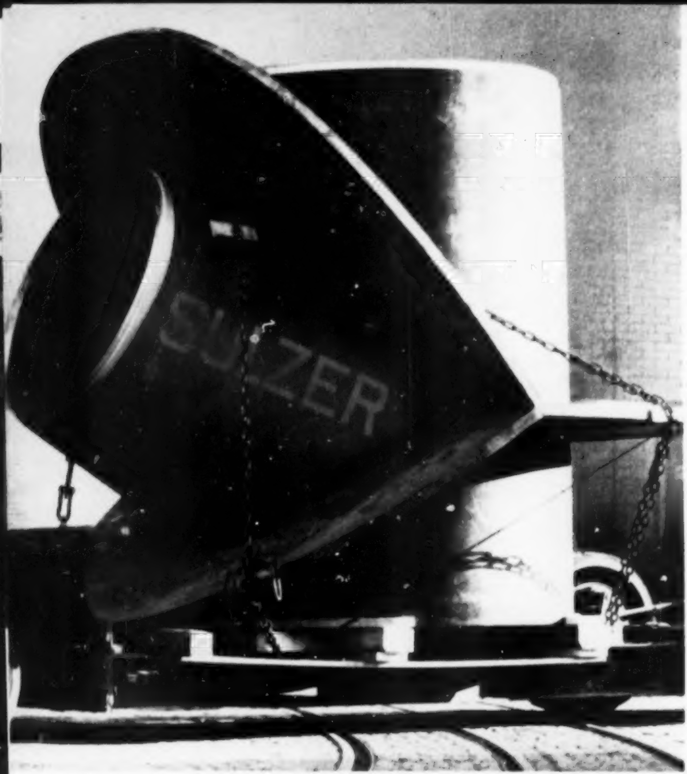


Fig. 1 — Y-Connection Between 80-In. Penstock Header and Water Turbine in High-Head Hydro-Electric Plant, Using Stiffening Collar of Sulzer Design

tures. Supplementary notched-bar impact tests at low temperatures, special series using the "Schnadt method", and fatigue tests on welded joints are often performed at the insistence of certain users. Another difficulty on the road toward standardization is that different steel manufacturers may propose their own weldability specifications which do not contain all the above-mentioned tests.

STEEL FOR WELDED PENSTOCKS

In view of this lack of agreement about the essential properties in a steel to be used for welded construction, it might be well to go to the other end of the scale and see how certain steels are performing in important structures on large machines. As a first example I want to show the performance in welded penstocks for hydro-electric power plants of which we have a great number. Most of the high-pressure plants built in Switzerland during the last few years have a head of over 500 ft. — even as high as 6600 ft. Penstocks carrying water from the intake in the mountains to the turbines down in the valleys must be strong enough for these pressures. Nowadays they are without exception welded. Steels usually specified are St. 60 (fine grained), AL DUR 50 and AL DUR 58, described briefly on p. 192.

The diameter of these penstocks varies between 40 and 80 in. and the plate thickness between 1½ and 2⅜ in. The calculated circumferential stress lies between 25,500 and 34,000 psi., whereas a joint-form coefficient $V = 1$ is assumed. Nonporous and slag-free welds must be shown by X-ray examination. Stress-relieving and machining of the seam surface are compulsory for the whole penstock. Suitable design and close control of the welders' qualifications are other indispensable items.

Werner Felix, testing engineer for Sulzer Brothers Ltd. of Winterthur, Switzerland, a firm that is famous for such work, tells me that in the Sulzer works they are convinced of the suitability of the slow bend test suggested by A. B. Kinzel (see his Campbell Memorial Lecture before the American Society for Metals, abstracted in *Metal Progress*, November 1947) or a similar test suggested by Kommerell (see p. 192). But no such test is made by the Sulzer firm as a condition of acceptance. Rather they rely upon the hardness of the steel as received and the decrease of Charpy impact strength in the heat-affected zone. He believes that to avoid brittle action in rigid structures, grain size should be 6 or finer (A.S.T.M. specification), the sulphur and phosphorus limited to 0.05 max. each (instead of the customary allowance of 0.07 max.), and the manganese should be no more than eight times the carbon in low-carbon steels and six times the carbon in the medium-carbon steels.*

The minimum for impact strength is 6 m-kg. per sq. cm. at 32° F. and 16 m-kg. per sq. cm. at 70° F. in the weld metal and 8 m-kg. per sq. cm. in the heat-affected zone at 70° F.

If, then, the measured Brinell hardness is less than 200, the steel is said to have very good weldability; if between 200 and 250 it is believed to have good weldability; between 250 and 325, sufficient weldability; and if the hardness is above 325, preheating at 400° F. and post-welding stress-relief are demanded.

Tests have confirmed that it is possible to improve remarkably impact strength, formability, and insensitivity to cracking, and to reduce the danger of brittle fracture by a special treatment of the steel plates as received from the mill. An example is 6% cold deformation and annealing at 480° F. for 30 min. Plant conditions will decide the costs at which these specially treated boiler plates can eventually be sold.

*Much more information on the above matters of steel quality and steel improvement is contained in Sulzer's excellent "Technical Bulletin", issues No. 4 for 1950 and No. 2 for 1951, respectively.

Testing by Detonation

Erich Volkhard, engineer at the Ateliers de Sécheron, lately reported some detonation tests on welded penstocks. This was an extensive series to examine the performance of welded pipes under great impact loads which correspond to the dangerous shocks from "water hammer" occurring in pressurized conduits. A cartridge was fired at the center of a short section of the pipe, already containing water. The liberated energy (measured by the weight of the cartridge) is directly proportional to the circumferential elongation of the pipe at the locus of the explosion. The first cartridge in any test was chosen so as to be a little too weak to rupture the pipe. Then the second explosive charge is adjusted so as to increase the circumferential elongation gradually (1 to 2% each time) until cracks occur. In one series of explosions a pipe with a longitudinal weld but without a circumferential weld (stress-relieved) was under study. No crack occurred up to a circumferential elongation of 24%.

In another test on a pipe made of aluminum-killed steel (yield point 57,000 psi.) having both longitudinal and circumferential welds made with lime-coated electrodes and stress-relieved, a little crack appeared in the circumferential weld at an elongation of 16%.

If stress-relieved pieces of pipe of either design were then welded – such as a weld bead run around the pipe a few inches from the joint – the elongation at rupture decreased to 6.5%, thus indicating the necessity of stress-relief. Volkhard concluded from these tests that it is safe to use the normal unalloyed boiler plate up to plate thicknesses of 0.8 in. for pressure vessels or penstocks subjected to heavy impact loading. For thicker plates, 1 in. and more, it is advisable to use aluminum-killed steels (fine-grained) for insurance against brittle fracture.

STEELS FOR RIGID BRIDGES

Progress in welded steel bridges is also very remarkable in Switzerland. In the last two years one highway and three railway bridges were built as completely welded structures. The biggest of them is the Tannwald Bridge for the Swiss Federal Railways. It is a continuous plate girder bridge 355 ft. long between abutments, supported on intermediate third points. Depth of girder is 110 in., and maximum thickness of web plate is 2⅜ in. The authorities naturally demanded that weldable material with high security against brittle fracture be used.

Weldability of the material was appraised according to standard No. 161 of the Society of the Swiss Engineers and Architects (principally chemical analysis and hardness). Security against brittle fracture and aging is measured by notched-bar impact tests and by Kommerell's bending test on a sample down which a welded bead has been run. This standard No. 161 demands the following qualities for welded joint and plate metal:

1. Tensile strength parallel and perpendicular to the weld at least as good as in the plate metal. Tensile strength of fillet welds (cross-weld specimen) greater than 42,500 psi.
2. Fatigue limit in tension (1,000,000 alternations) greater than 22,700 psi. perpendicular to the weld and greater than 25,600 psi. parallel to the weld.
3. Brinell hardness lower than 180.
4. Keyhole specimen impact strength: Greater than 10 m-kg. per sq. cm. in base material. Greater than 8 m-kg. per sq. cm. in weld deposit. Greater than 6 m-kg. per sq. cm. in heat affected zone.
5. Quality in the transverse bend test is measured by a coefficient, K, figured from the formula

$$K = \frac{50\,S}{r}$$

where S is the thickness of the specimen and r is the mean radius of bend without fracture. The coefficient K must be greater than 30 when the notch is on the compression side of the bent specimen, and greater than 25 if on the tension (for plate thicknesses up to 0.80 in.)

This transverse bending test is a very severe test, but the impact test and hardness also well indicate the weldability of steel.

When bids were asked for the Tannwald Bridge it was emphasized that the greatest care must be taken in choosing the material. Wartmann Ltd., the successful contractor, proposed to test the material by the Schnadt notch-impact test, in addition to the methods specified in the S.I.A. standard No. 161. This proposal was accepted by the Swiss Federal Railways, and the material was simultaneously tested by surface weld bending tests. (See data on p. 192.)

Two steels were supplied for this bridge, St. Z1 and St. 37.161. Their chemical compositions are:

	St. Z1	St. 37. 161
Carbon	0.13	0.15
Sulphur	0.05	0.06
Phosphorus	0.05	0.06
Phosphorus and Sulphur		0.10

Minimum mechanical properties of both of these steels are as shown overleaf.

Yield point	34,000 psi.
Tensile strength	52,500 to 64,000 psi.
Elongation	25%
Quality coefficient*	> 11
Bending coefficient, K	60 for t < ¾ in.
	40 for thicker sections
Schnadt test at 0° C.	8
Same after aging	6

*See p. 192.

No difficulty was found in meeting these specification values by the manufacturers—Stahlwerke Differdingen in Luxemburg (basic bessemer steel) and Ougrée in Liège, Belgium (aluminum-killed openhearth steel). Nevertheless, there arose some difficulties with the bending tests, since the manufacturers were using the German or Austrian standard. To attain the high tensile strength with specified carbon content and bending coefficient was not easy in the thicker plates, between 1⅛ and 4⅛ in., used in this bridge. (See p. 192.)

As a direct consequence of this very severe control of weldability, two steels of different qualities were used. For members taking high tensile stress, St. Z1 was chosen. For those carrying moderate tensile stress (or high compression stress) St. 37.161 was used. Since there arise no sharp stress concentrations in main members of plate girder bridges, it was possible to tolerate steels with a certain susceptibility to brittleness and aging.

TESTS ON ELECTRODES

Data about electrodes and tests on welded samples from this bridge project may also be of interest. Electrodes exceeded specification values considerably:

	Specified	Actual
Yield point	38,000	62,500
Tensile strength	62,500	78,000
Elongation	20%	36%
Fatigue strength	40,000	61,000
Keyhole impact		27 to 32
Same after aging		25 to 29
Brinell hardness		176

Required values for welded joints were as follows:

Fatigue strength	22,800 psi.
Bending coefficient K	40 for t < ¾ in.
	25 for t > ¾ in.
Notched bar impact	
Keyhole in weld metal	8 m-kg. per sq. cm.
Keyhole in transition zone	6
Maximum hardness	200 Brinell
Schnadt test	
Notch at root of weld	8
Notch at edge of transition zone	8

I want to emphasize that our experience in Switzerland with steels proof against brittle fracture is still very recent. Therefore, notched-bar impact tests, transverse bending tests and surface weld bending tests are always made simultaneously. With these tests available the steel fabricator is relatively free in choosing his steel suppliers.

STEELS FOR WELDED SLUICE GATES

Construction of welded sluice gates is especially remarkable in connection with the building of low-head hydro-electric power plants on rivers. For example, at the Birsfelden power plant there are five sluice gates in a barrage on the Rhine, each of which has to withstand a pressure of 2130 tons (Fig. 2). For this work the requirements of the S.I.A. standard No. 161 described above were enforced, so the steel was chosen by the same principles as for the Swiss railway bridges. The tension chord and the stiffeners of the upper and lower gates carry mainly static tensile stress; nevertheless, the structure retains remarkable residual welding stresses and builds up large three-dimensional stresses in service. These sluice gates were made of nonaging steel roughly corresponding to the German specification for St. 40.21 (the steel supplied was actually an 0.18% carbon max. "HMS 42" of Rheinische Röhrenwerke) which has high security against brittle fracture. Tensile strength was in the 57,000 to 72,000-psi. range and the yield point 34,000 psi. Specified values in m-kg. per sq. cm for toughness (keyhole specimen) were:

	Longitudinal	Transverse
Steel as rolled	9 at 70° F.	7 at 70° F.
	6 at 0° F.	3 at 0° F.
Aged 30 min. at 480° F.	4 at 70° F.	3 at 70° F.

Schnadt test on welded joint, minimum values: 8 with root of notch at base of weld metal; 8 with root of notch at base of transition zone.

Buss Ltd., of Pratteln, Basel, Switzerland, fabricators of this work, used the Schnadt notch-impact test for judging the weldability of the steels because the engineers believed it is possible to examine the properties of the heat-affected zone by means of notches with different sharpness. Another advantage of these tests is that one can predict if it is necessary to preheat the steel before welding or if it is possible to weld it at ambient temperature. In this work, for instance, it was found that all plates thicker than 1 in. had to be preheated at 100° C. in order to be sure that the heat-affected

zone had no tendency toward brittle fracture.

In this work, as in all welding, the welding electrodes and the welding procedure must be very carefully chosen. However, a discussion of these problems is beyond the scope of the present article. Another matter of great concern is the weldability of alloyed constructional steels and of high-alloy corrosion or heat resistant steels, both forged and cast, but again space does not permit more than a mention of the fact that European engineers have intensively studied these problems.

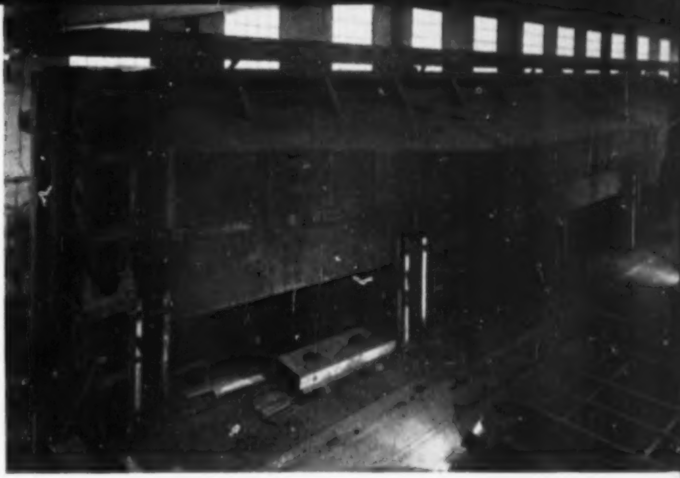


Fig. 2 – Welded Sluice Gate on Erecting Floor of Buss, Ltd., Pratteln, Basel, Switzerland – a Rigid Structure Containing High Residual Stresses, and Designed to Withstand Heavy Three-Dimensional Stress

THE PROBLEM OF TRI-AXIAL LOADING

I will not close this article without pointing out the remarkable work of Professor Ros in publications No. 172 and 173 of the Swiss Material Testing & Research Institute of Zurich, Switzerland. These give valuable information about the behavior of weld metal and heat-affected zone under different types of fatigue load and enable the designer to calculate the allowable stresses quite accurately. When made under optimum conditions, it was proven that the weld metal has as good and even better resistance and deformation properties than normal and high-class steel.

These recently published researches deal particularly with the endurance of hollow test bars of pure weld metal, filled with liquid under pulsating pressure and therefore subjected to three-dimensional stresses. Specimens of pure weld metal were also examined under static internal pressure, and under longitudinal tension plus pressure. It may be said that the conclusions reached by Professor Ros conform to the theory of O. Mohr which says that the so-called "mean main stress" is not the criterion for rupture.

It was also shown that the oft-feared biaxial loads do not create a higher danger of rupture than mono-axial tension, either when static or when alternating loads are applied.

CONCLUSION

The examples discussed in this article show that the Swiss manufacturers of massive objects working under high stresses are very much interested in the question of "weldability". Certain experts consider that, for the moment, the question of "brittle fracture" is merely "in fashion" and that its importance is overestimated. A certain danger may arise from excessive demands which lead to the exaggerated trends in electrode manufacture toward those with unusually good brittle fracture properties, but which perhaps have other disadvantages. For example, it is plain that certain Swiss electrodes which for years have been renowned for their good properties (strength and ductility) could not be used for the big and important jobs because their "weldability" as measured by the new methods is insufficient.

The same danger exists in the development of special welding steels. If, for example, a steel can be made secure against brittle fracture only by heat treatment – which is true of Thomas or basic bessemer steel, the most widely used variety in Europe – quite unpleasant surprises may arise during the final heating for aligning, especially when using the aluminum-killed varieties.

Therefore, I wish very much to emphasize that the Swiss experts interpret "weldability" in quite different ways – but always very comprehensively. Especially in our country, a particularly good property or a "star performance" in one respect is not too impressive. We consider that the totality of all the details, such as careful choice of material, good design, welds performed by trained workmen, rigid examination of welders, minute control of the weld in operation, and a thorough and searching final inspection all are of great importance in producing a machine or structure which will perform satisfactorily in service. We also believe in marshalling all our past experience with similar welding problems when considering an advance into a new field.

This minute care, everywhere and every time, and our desire to produce high-quality products, have helped the Swiss manufacturers, engineers, and welders to construct important welded objects and have preserved us from bad set-back.

Evolution of the Thomas (Basic

As is well known to all metallurgists, the nature of the iron ores of Western Europe has resulted in a widespread use of the Thomas process, that is to say, refining the pig iron into steel in a basic-lined converter.

The ores of the Lorraine deposit form the essential raw material of the iron and steel industries of France, Belgium and Luxemburg. This deposit is the biggest proven reserve in the world of iron ore usable without concentration; it has been evaluated definitely at 7 billion tons. The pig iron contains about 1.80% phosphorus, which is the most favorable analysis for blowing on a basic lining. The iron ores mined in Great Britain and Germany (as well as the much richer ores of north Sweden used in Germany, in Great Britain and in Belgium to improve the burden) are also high in phosphorus, so that, excepting a small supply from North Africa, the iron and steel industry of Western Europe uses almost exclusively high-phosphorus ores.

As a result, the Thomas process plays a leading part in the industry of those countries, making about 16,500,000 short tons out of the 50 to 55 million tons total of Great Britain, Germany, France, Belgium, Luxemburg and the Netherlands. Even though basic converters are operated by only two plants in Great Britain, Thomas steel makes up 40% of the German production, 60% of the French production, 85% of the Belgian production and practically all of Luxemburg's. The extreme desire evident on the Continent since the end of the War for improving this process is therefore readily understandable. The numerous investigations to this end will now be summarized briefly.

As a result of the rapidity of the pneumatic refining operation, which lasts 15 min. only, it is difficult to obtain the same consistency of analysis as in the more deliberate openhearth or electric furnace refining, especially as to the phosphorus content.

Moreover, ordinary Thomas steel usually contains a little more oxygen and especially more phosphorus and nitrogen than openhearth steel. This makes it less well fitted for applications

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Bessemer)

Steelmaking Process in Europe

requiring a great deal of cold deformation without aging or risk of brittleness – as in wiredrawing, deep drawing or in welded fabrication.

Efforts to improve this steel should therefore aim at two objectives – (*a*) increasing the consistency of analysis and (*b*) decreasing the average phosphorus and nitrogen contents.

Control of the basic bessemer blow is often hindered by considerable "spitting" toward the middle of the decarburizing period, resulting in costly metal losses. It is then necessary to slow down the blow and the consistency of the analysis thereby suffers. This spitting has been studied by M. Leroy, of IRSID, in cooperation with several works and the Laboratoire Dauphinois d'Hydraulique of Grenoble, specialists in hydrodynamics and scale models,[1]* and they find that it is caused by two simultaneous phenomena:

1. Under the blowing action the liquid mass swells, causing a wave to run around the converter wall at about one complete turn every 2 sec. When the height of this wave overtops the spout, metal spills out at each turn.

2. At the beginning of the blow, oxidation of the silicon forms a very foamy silicoferrous slag. The added lime flux neutralizes this foaming tendency only gradually, and the foam formed in the meantime increases the total volume of the charge and, as a consequence, the height of the revolving wave.

Steps to avoid these difficulties include

1. Redesigning the vessel's shape so as to hinder, as much as possible, the formation and the motion of the wave.

2. Reducing the silicon as much as possible.

The first objective is obtained either through the use of as large a converter as possible so as to reduce the depth of the bath, and by the somewhat revolutionary plan of minimizing the annular area between the converter wall and the portion of the base occupied by the tuyeres. Tuyeres, in fact, must extend clear over to the sidewall, if possible. The first of these factors is more important than the second, so that, when the lining is wearing thin, the blow improves because the favorable effect of the decrease of the bath depth outweighs the adverse effect of the increase of the annular surface around the tuyeres.

As to the need for pig iron with low silicon, this has long been known to all converter operators. They will endeavor to keep silicon below 0.45%. This is, however, very difficult to guarantee from blast furnaces handling a charge with a $CaO:SiO_2$ ratio in the slag below 1.20, for instance, or even of the order of 1.00.

But something of this sort must be done in Europe since more than half the Lorraine ores are of a siliceous nature. It is, therefore, most important to find a means of desiliconizing the liquid iron between blast furnace and converter. M. Leroy has also developed such a means of pre-refining the iron by a jet of high-pressure oxygen (220 psi.) blown through a pipe ending a few centimeters above the metal's surface. Results so obtained are better than with an immersed lance using a lower pressure[2], and are further improved by a little powdered lime on the iron to neutralize the silica as it is formed.

End-Point Determination – The blowing conditions within the converter being thus improved, it remained to improve the accuracy whereby the end point can be determined. End point is usually estimated by the operator according to the appearance of the flame, taking into account the apparent temperature of the charge. Such an estimation is subject to many uncertainties, even for an experienced operator, so numerous efforts have been made to give

*Citation No. 1 in the bibliography found on p. 174.

him some instrumental aids. Spectrographic methods have failed because the dephosphorizing flame is laden with dust, and emits a continuous spectrum completely devoid of any characteristic line whose appearance or disappearance could be used as reference.

By recording the ratio of radiations emitted by the flame in two bands, red and purple, Professor Breckpot of the Belgian University of Louvain has succeeded in obtaining a "hook" on the recorded curve that could be used as a signal[3], but the position of this signal relative to the correct stopping point, unfortunately depends largely upon the temperature of the charge – the higher the temperature, the longer the continuation of the blow.

My associate, M. Galey of IRSID, however, has obtained a similar signal which is almost completely independent of the temperature by taking aim through the flame at a reference lamp with a tungsten filament[4]. The opacity of the flame is thus measured, and it varies suddenly at the moment when dephosphorization is complete. A simultaneous record of the opacity and the brightness of the flame* enables one to determine the true temperature of the flame; this seems to be related to the thermal evolution of the charge itself. In view of the above discoveries, steelmen operating Thomas converters will have at their disposal in the near future and instrument recording simultaneously this true temperature of the flame and its opacity, from which the correct end of the blow can be accurately determined.

SULPHUR, PHOSPHORUS AND NITROGEN

It is to be expected that the use of such instrumental aids as mentioned above will increase the uniformity (narrow the spread) of analysis in Thomas steel. As a matter of fact, other techniques developed in Europe in the last ten years have also improved substantially the mean itself. Better temperature control by using the immersion pyrometer has already improved dephosphorizing considerably, which is hindered by too high a temperature. If the first slag is removed and then followed by an extra blow of some seconds after the addition of a small amount of calcium or sodium carbonate, phosphorus can be driven down still further to less than 0.035% – that is, of the same order as in openhearth steel.

The converter blow eliminates a substantial portion of the sulphur of the iron, especially when a low-sulphur lime is used which has been screened to free it from the dust which is always higher in sulphur than the bigger chips. If iron with extra-high sulphur must be handled, it should be desulphurized by soda carbonate in the ladle, or by the process developed in Sweden by Prof. Bo Kalling[5] of Domnarvet† of tumbling the molten iron in a revolving furnace with powdered lime.

As for openhearth or electric steel, the Perrin process for refining while mixing with a liquid slag is also able to give very low sulphur contents, if necessary. But too high a nitrogen content may be even more deleterious to quality than phosphorus.

Since liquid iron dissolves nitrogen from the air blast, especially toward the end of the decarburizing period and the beginning of dephosphorization, a Thomas steel made without special precautions normally has higher nitrogen than a good openhearth steel. The nitrogen content of the latter is about 0.005 to 0.006%, while in Thomas steel the nitrogen content may vary between 0.017% for very hot heats and a mean value of 0.008% in more favorable conditions when the temperature is correct. This nitrogen content can be lowered much more by using different processes contriving in one way or another to reduce the volume of nitrogen going through the bath, its partial pressure, its surface area and the duration of its contact with the metal.

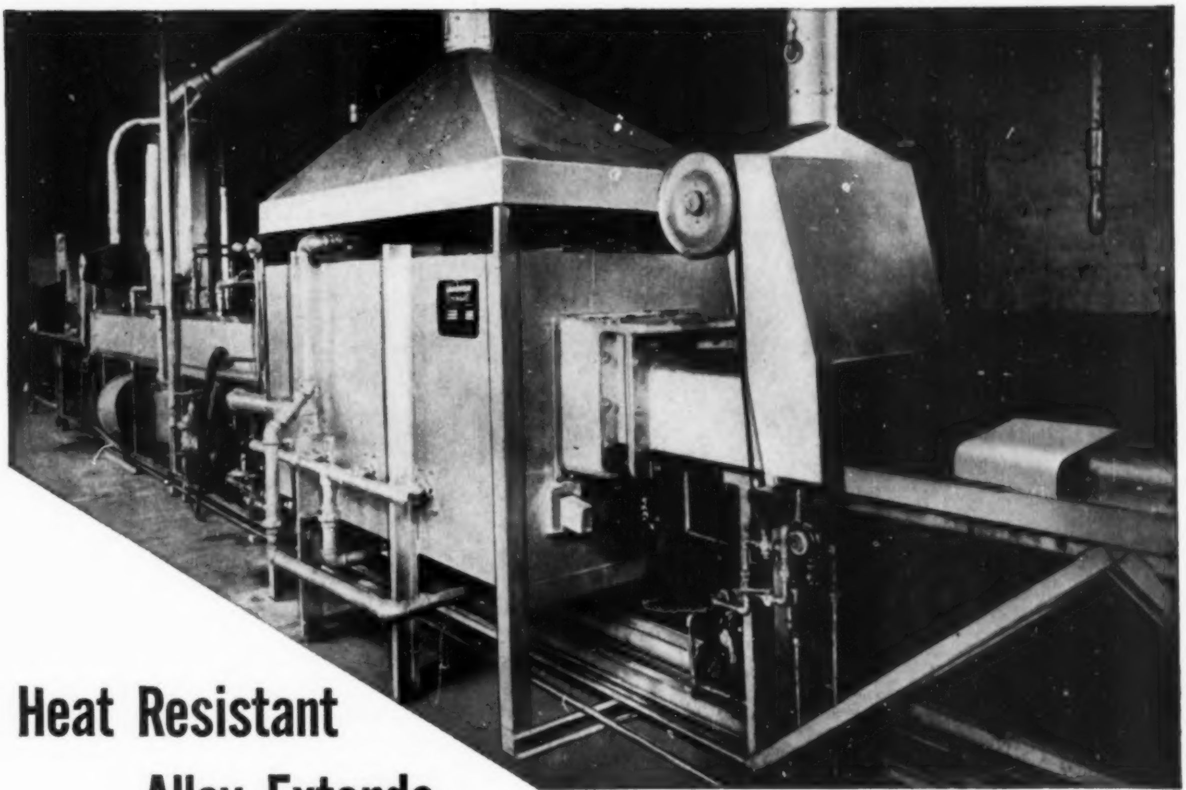
For instance, an ore addition to the charge supplies an extra amount of refining oxygen without bringing more nitrogen to the charge. Used in Germany during the war, the so-called HPN process enabled some plants to reduce the mean nitrogen content of the heats from a former 0.015% to about 0.010%. This process, taken to Great Britain by the late Dr. Dickie and supplemented with a very close control of the blowing conditions, including a decrease of the depth of the bath, has yielded excellent results at the Corby steel plant[6].

Blowing in a tilted converter to reduce the distance the air bubbles travel through the liquid metal has also given some good results in Germany at the Mannesmann works (MA process) at Hückingen, but this process has numerous practical drawbacks, such as a longer blow and a shorter life of the linings.

(Continued on p. 168)

*Using the so-called Kurlbaum method.

†See his article on p. 108 of this issue also reference 5 in the bibliography, p. 174.



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Standard Analyses of German Alloy Steels

Designation	Chemical Composition						Tensile Strength	
	Carbon	Manganese	Silicon	Nickel	Chromium	Molybdenum	Water Hardened	Oil Hardened
Carburizing Steels; First German Standards (Circa 1925)								
EN 15	0.10-0.17	0.50 max.	0.35 max.	1.50±0.25	0.20 max.		85,000-115,000	
ECN 25	0.10-0.17	0.50 max.	0.35 max.	2.50±0.25	0.75±0.20		127,500-155,000	115,000-140,000
ECN 35	0.10-0.17	0.50 max.	0.35 max.	3.50±0.25	0.75±0.20			127,500-170,000
ECN 45	0.10-0.17	0.50 max.	0.35 max.	4.50±0.25	1.10±0.20			170,000-200,000
....	0.12-0.16	0.40-0.60	0.35 max.	2.00-2.30	2.00-2.20	0.20-0.30		170,000-200,000
Nickel-Free Carburizing Steels (1935-1940)								
EC 30	0.10-0.16	0.40-0.60	0.35 max.		0.30-0.50		78,000-100,000	
EC 60	0.12-0.18	0.40-0.60	0.35 max.		0.60-0.90		100,000-127,000	
EC Mo 80	0.13-0.17	0.80-1.10	0.35 max.		1.00-1.30	0.20-0.30		120,000-155,000
EC Mo 100	0.18-0.23	0.90-1.20	0.35 max.		1.10-1.40	0.20-0.30		155,000-205,000
Molybdenum-Free Carburizing Steels (1950)								
15 Cr 3	0.12-0.18	0.40-0.60	0.15-0.35		0.50-0.80			85,000-120,000
16 Mn Cr 5	0.14-0.19	1.00-1.30	0.15-0.35		0.80-1.10			115,000-155,000
20 Mn Cr 5	0.17-0.22	1.10-1.40	0.15-0.35		1.00-1.30			127,500-170,000
15 Cr Ni 6	0.12-0.17	0.40-0.60	0.15-0.35	1.40-1.70	1.40-1.70			140,000-185,000
18 Cr Ni 8	0.15-0.20	0.40-0.60	0.15-0.35	1.80-2.10	1.80-2.10			170,000-205,000
Heat Treating Constructional Steels; First German Standards (Circa 1925)								
VCN 15w	0.25-0.32	0.40-0.80	0.35 max.	1.50±0.25	0.50±0.20			92,500-107,500
VCN 15h	0.32-0.40	0.40-0.80	0.35 max.	1.50±0.25	0.50±0.20			107,500-120,000
VCN 25w	0.25-0.32	0.40-0.80	0.35 max.	2.50±0.25	0.75±0.20			100,000-120,000
VCN 25h	0.32-0.40	0.40-0.80	0.35 max.	2.50±0.25	0.75±0.20			115,000-135,000
VCN 35w	0.20-0.27	0.40-0.80	0.35 max.	3.50±0.25	0.75±0.20			107,500-127,500
VCN 35h	0.27-0.35	0.40-0.80	0.35 max.	3.50±0.25	0.75±0.20			127,500-150,000
VCN 45	0.30-0.40	0.40-0.80	0.35 max.	4.50±0.25	1.30±0.20			142,500-165,000
Nickel-Free Constructional Steels (1935-1940)								
VC 135	0.30-0.37	0.50-0.80	0.35 max.		0.90-1.20			107,500-127,500
VC Mo 125	0.22-0.29	0.50-0.80	0.35 max.		0.90-1.20	0.15-0.25		92,500-115,000
VC Mo 135	0.30-0.37	0.50-0.80	0.35 max.		0.90-1.20	0.15-0.25		115,000-142,500
VC Mo 140	0.38-0.45	0.50-0.80	0.35 max.		0.90-1.20	0.15-0.25		135,000-155,000
VC Mo 240	0.38-0.43	0.50-0.80	0.35 max.		1.60-1.90	0.30-0.40		155,000-185,000
Low-Alloy Constructional Steels (1950)								
40 Mn 4	0.36-0.44	0.80-1.10	0.25-0.50					115,000-135,000
30 Mn 5	0.27-0.34	1.20-1.50	0.15-0.35					115,000-135,000
37 Mn Si 5	0.33-0.41	1.10-1.40	1.10-1.40					127,500-150,000
42 Mn V 7	0.38-0.45	1.60-1.90	0.15-0.35				Note: 0.07-0.12V	142,500-170,000
34 Cr 4	0.30-0.37	0.50-0.80	0.15-0.35		0.90-1.20			127,500-150,000
41 Cr 4	0.38-0.44	0.50-0.80	0.15-0.35		0.90-1.20			127,500-150,000
25 Cr Mo 4	0.22-0.29	0.50-0.80	0.15-0.35		0.90-1.20	0.15-0.25		115,000-135,000
34 Cr Mo 4	0.30-0.37	0.50-0.80	0.15-0.35		0.90-1.20	0.15-0.25		127,500-150,000
42 Cr Mo 4	0.38-0.45	0.50-0.80	0.15-0.35		0.90-1.20	0.15-0.25		142,500-170,000
50 Cr Mo 4	0.46-0.54	0.50-0.80	0.15-0.35		0.90-1.20	0.15-0.25		157,500-185,000
30 Cr Mo V 9	0.26-0.34	0.40-0.70	0.15-0.35		2.30-2.70	0.15-0.25	Note: 0.10-0.20V	180,000-207,500
36 Cr Ni Mo 4	0.32-0.40	0.50-0.80	0.15-0.35	0.90-1.20	0.90-1.20	0.15-0.25		142,500-170,000
34 Cr Ni Mo 6	0.30-0.38	0.40-0.70	0.15-0.35	1.40-1.70	1.40-1.70	0.15-0.25		157,500-185,000
30 Cr Ni Mo 8	0.26-0.34	0.30-0.60	0.15-0.35	1.80-2.10	1.80-2.10	0.25-0.35		177,500-207,500

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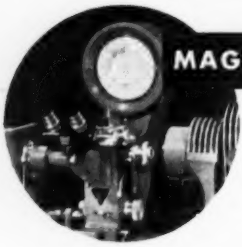

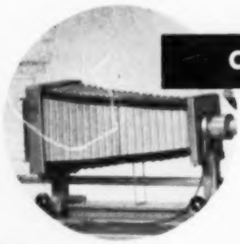

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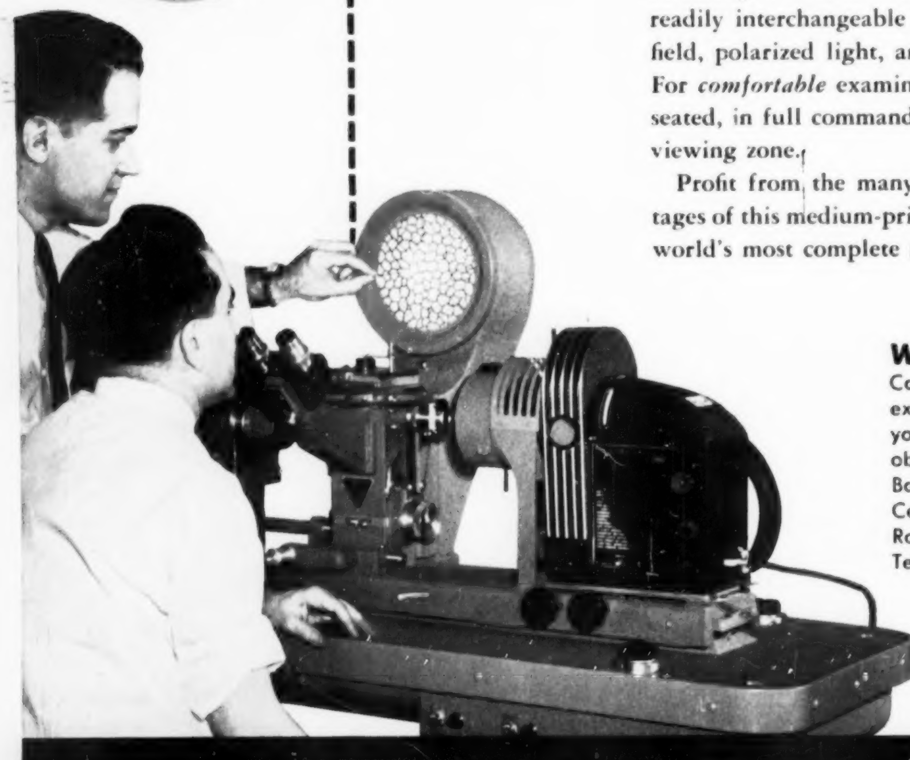

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By F. W. BRUHL
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Krefeld, Germany

Developments in German Constructional Steels to Conserve Scarce Alloys

THE EVOLUTION which alloy steels have undergone in the last two decades is characterized, among other things, by efforts to use the alloying metals as economically as possible. Thoroughgoing study of the effect of individual alloys has resulted in a series of new compositions for constructional steels which are distinguished by steadily decreasing alloy content. Nickel, in particular, has been conserved – and to a certain extent, molybdenum. Such changes have been made without lowering the behavior of these new steels in service; some, in fact, have superior fabricating properties to the ones previously used.

This evolution has been pushed forward vigorously in both the United States and in Germany, and it is interesting to see that the course adopted in Germany is different from that which American metallurgists have found suitable for the conditions there. The list of German standard steels for carburizing and for heat treating will be cited at three important stages in this development in order to make clear the present status.

CARBURIZING STEELS

The first German standard (DIN 1662) for alloy carburizing steels included only one nickel steel and three nickel-chromium steels with nickel up to 4.5%. The chemical requirements of this standard are summarized in the top lines of the data sheet, p. 96-B. The tensile strength to be obtained after hardening is also noted. The characteristics of these steels should be so well known that it is unnecessary to go into more detail about them here.

In 1935, as a supplement to these nickel and nickel-chromium steels, chromium and chromium-molybdenum carburizing steels were standardized and a great tonnage of them produced in the following decade. Analyses and tensile properties are presented in the second section of the data sheet. These steels were an effective addition to the nickel-chromium steels.

However, the situation quickly emerged that they behave quite differently from the nickel steels in some important respects, especially in machining and heat treating. Because chromium and molybdenum have a strong affinity for carbon, thus forming carbides very easily in the carburizing process, free carbides appear in the carburized layer much more easily under similar conditions in the new nickel-free steels than in the nickel-chromium. It was necessary to go over from the rapid carburizing compounds used before to ones that give a milder surface hardening effect.

It is particularly important to point out that no difference can be detected in salt bath carburizing between the chromium-molybdenum

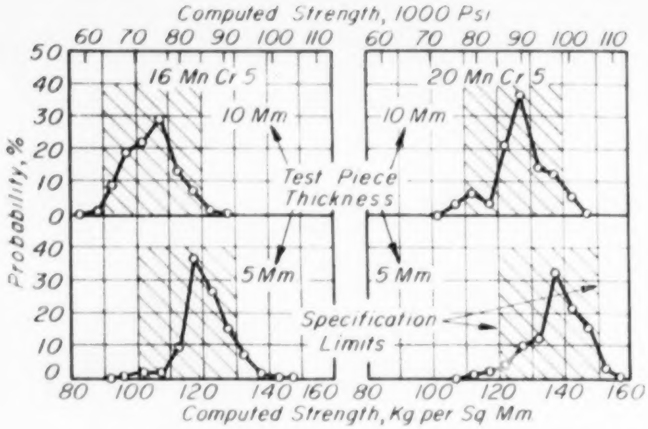


Fig. 1 – Probability Curves From Numerous "Blank Hardening" Tests on Two of the New Carburizing Steels. Strengths computed from Brinell hardness

and nickel-chromium steels, and the salt bath was widely used by European automobile manufacturers; consequently, their previous methods of operation could be continued without change after introduction of the more economical chromium-molybdenum steels.

Chromium-molybdenum steels require a somewhat higher hardening temperature, 1510 to 1545° F., while that for the nickel-chromium steels usually lies between 1455 and 1490° F. This extra 50 degrees may lead to greater distortion in complicated shapes such as gears, and can also result in somewhat greater scaling of the surface. This must be considered in the design and fabrication in order to avoid undue rejections.

The appreciably better machinability of chromium-molybdenum steels is of great importance. The life of the tool is longer at the same machining rate, or it is possible to select higher cutting speeds than before.

The carburized layer of chromium-molybdenum steels shows hardnesses of Rockwell C-65 or C-66, as against C-62 or C-63 for the earlier series of steels. This higher hardness results in very good operating and wearing qualities. The hardened skin is free of the austenitic areas that may very easily remain in hardened nickel-chromium steels having nickel above 3.5%.

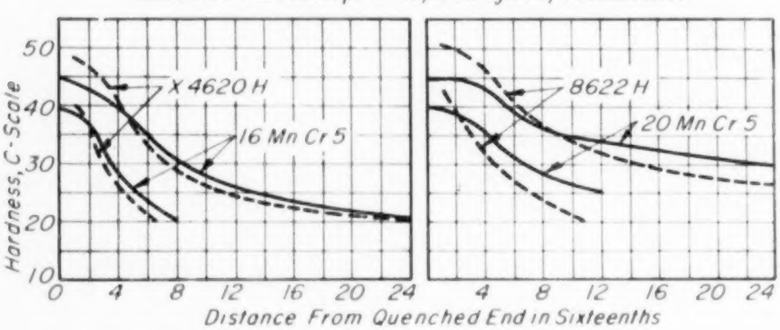
In consideration of these differences, the chromium-molybdenum steels were very quickly adopted in Germany, and proved their worth in all instances.

Manganese and Triple-Alloy Steels – As an aftermath of the last War, especially at the time of the Korean crisis, it became necessary to economize on molybdenum as well. After a long study of these carburizing steels, chromium-manganese steels were produced. (For the highest requirements, the chromium-nickel steels with additions as shown the third section of the data sheet, p. 96-B, were added to the German standards.)

The chromium-manganese steels can be carburized in the same routine as the chromium-molybdenum steels. Mild carburizing compounds or the usual cyanide-containing salt baths are quite sufficient. Hardening temperatures are the same, so that deformation in hardening is also practically the same. Machinability of the new steels is still better, as compared to the chromium-molybdenum steels EC Mo 80 and 100. These steels were introduced without any difficulty in the consumers' shops.

German Hardenability Test – The German standard specifications for these steels contain, in addition to the chemical analysis, a required hardness as determined on plates of different thicknesses after a so-called "blank hardening". Plates with a thickness of 5 mm., 10 mm., and so on, are heated to the prescribed temperature and then quenched in oil or water, as directed. The Brinell hardness of each sample is then determined at various previously selected places. Frequency curves for a large number of such blank hardening tests are shown in Fig. 1, for 16 Mn Cr 5 and 20 Mn Cr 5 steels, and it can be seen that the requirements of the standard as shown by the hatched area are well met. In addition, in Fig. 2 the range of Jominy hardenability curves is shown – like-

Fig. 2 – End-Quench Tests on German Standard Chromium-Manganese Steels for Carburizing Compare Favorably With American Steels Containing Nickel and Molybdenum. See Data Sheet, p. 96-B, for analyses of German steels



wise taken from a large number of tests. These bands for chromium-manganese steels compare favorably to those specified in the United States for steels containing nickel and molybdenum, such as S.A.E. X 4620 H and 8622 H.

In the carburized steels which are generally used in automobile construction for moving parts in which high stresses or impacts may occur, toughness is of particular significance. Impact tests on specimens that resemble a gear tooth show that machinable nickel-free and molybdenum-free steels do not stand far below the nickel-chromium steels in toughness. Figure 3 shows the test piece; Table I (overleaf) summarizes the results, which are in accord with experience in more than a decade of industrial use. It can be said that the nickel-free carburizing steels of the immediate prewar era are as tough as the time-honored high nickel-chromium steels, and that the postwar chromium-manganese steels are measurably superior. Thus, the creation of the chromium-manganese steels may be regarded as quite an industrial triumph.

Both of the nickel-chromium steels 15 Cr Ni 6 and 18 Cr Ni 8 now in the German standard specification have a new combination or "balance" of chromium and nickel. The nickel has fallen to 2% or less, and the chromium always equals the nickel. We believe that such steels reach the highest strength with maximum toughness. They find use, pre-eminently, in very highly loaded truck parts and in similar severe service.

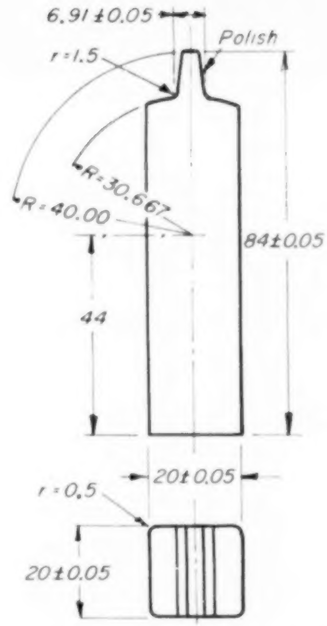
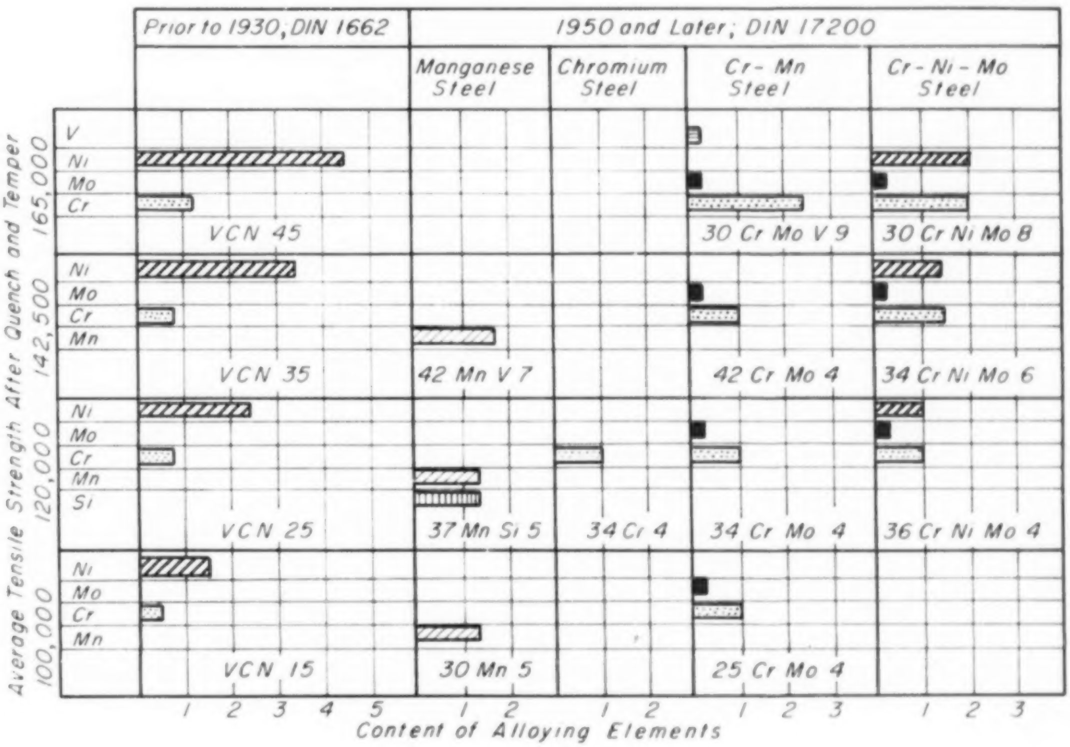


Fig. 3 – Simulated Gear Tooth Used as Impact Test of Carburized and Hardened Part. See Table I for summary of results

Fig. 4 – Bars Show How Nickel Is Conserved in Present-Day German Alloy Steels at the Expense of the More Available Chromium and Manganese



Through Hardening Steels

The development of heat treating steels shows general similarities to the carburized steels. The nickel-chromium steels that were early standardized are summarized in the lower part of the data sheet, p. 96-B. These were later replaced by chromium-molybdenum steels, while the last group in the data sheet covers the present situation. In addition to the chemical analyses, German standards specify the tensile properties after heat treatment of certain cross sections up to about 10 in. in diameter. As can be seen the present list includes manganese steels, manganese-silicon steels, carbon-chromium steels (such as those which constitute nearly one quarter of the current American production), chromium-molybdenum steels, and chromium-nickel-molybdenum steels.

The development of alloyed heat treating steels in Germany is shown graphically in Fig. 4, clearly indicating how the alloying ingredients have changed in the course of 20 years – particularly toward the use of smaller amounts of the scarce elements or the use of cheaper alloying constituents to attain the same tensile properties. For this diagram I am indebted to Heinz Kiessler – see "Status and Development of Heat Treatable Steels," *Stahl und Eisen*, Vol. 71, 1951, p. 433 to 440.

For highest strength with maximum toughness, the same chromium and nickel combinations are found in the heat treating steels as in the carburizing steels, for example, 1.5% Ni and 1.5% Cr. They also have a small addition of molybdenum, mainly to decrease temper brittleness.

Hardenability is of particular importance in constructional alloy steels. In Fig. 5 the median hardenability curves are plotted for the most important steels. Their hardenability is of the same order as that of comparable American steels. Maximum hardness (which depends on the carbon content) is lower because the German standards contain no high-carbon steels, whereas many American series of standard steels have analyses going to 0.60% carbon.

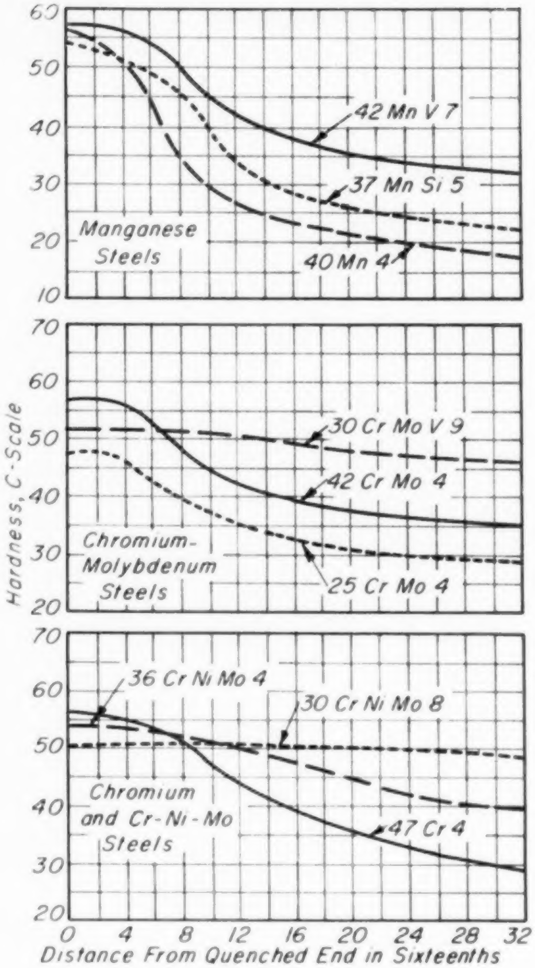


Fig. 5 – Median Hardenability Curves of Principal German Alloy Steels Specified by Most Recent Standard (DIN 17200)

Table I–Impact Tests on Simulated Gear Teeth

	ECN 45	EC Mo 100	20 Mn Cr 5
Nature	High Ni-Cr	Cr-Mo	Mn-Cr
Era	Traditional	Prewar	Postwar
Impact resistance, m-kg. per sq.-cm.			
Average	9.2	9.3	11.1
Range	0.7	0.8	0.6
Case depth, mm.	0.7	0.9	0.8
Surface hardness	C-62 to 63	C-64 to 65	C-65 to 66
Core strength*, psi	195,000	215,000	215,000

*Calculated from hardness

Conclusion – This brief survey of the development of alloyed carburizing and heat treating steels in Germany should show that the manner in which the most economical use of alloying elements has been approached in Germany is very different from the course pursued in America. It seems probable that an evaluation of the experience on both sides in this field would permit still more progress toward economical use of alloying elements.

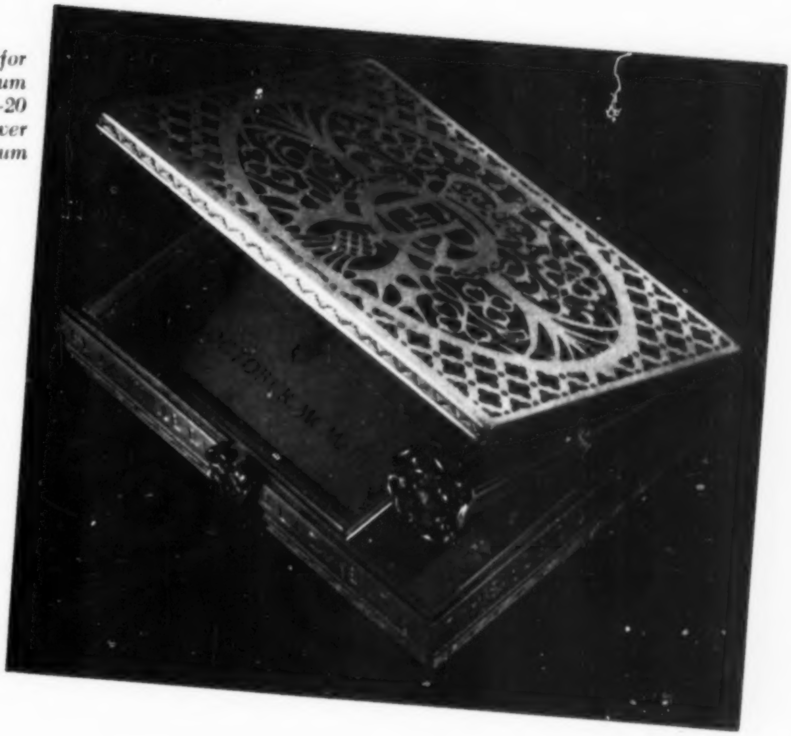


Fig. 1 -- Powder and Lipstick Case for Queen Elizabeth Made of the Platinum Group of Alloys. Case and cover of 80-20 platinum-iridium. Mirror inside cover is of rhodium, the latch is of osmiridium

By TOM BISHOP, Editor
Metal Treatment and Drop Forging
London, England

British Advances in Metals, Fabrication Methods and Applications

Some of the latest trends in Britain in the treatment and use of metals are included in this annual review. Much has to be left unsaid in the space available, for such a survey of many subjects, in which techniques are continually improving, must of necessity be incomplete. No mention of aluminum and its alloys will be included, since this topic is given especial attention in another article in this issue of *Metal Progress* (p. 112).

NEW ALLOYS

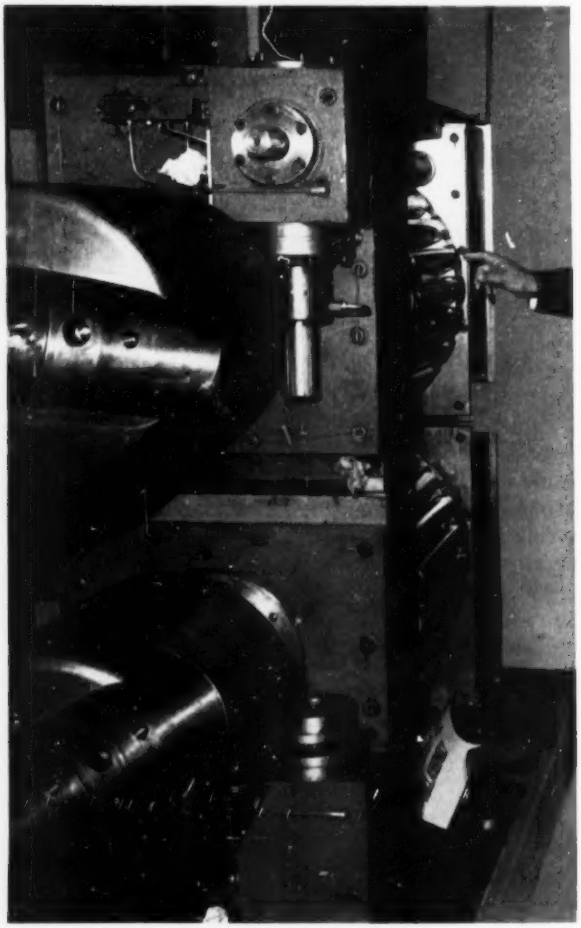
High-Strength, Low-Alloy Steel – Work during the preceding years in the research and development department of United Steel Companies, Ltd., Sheffield (W. E. Bardgett, research manager), has resulted in the production and satisfactory use of a very considerable amount of a carbon-molybdenum steel fortified with boron. It is marketed by one of the associated companies, Samuel Fox & Co., Ltd., under the trade name "Fortiweld"; its typical analysis is 0.12% C, 0.5% Mn, 0.2% Si, 0.5% Mo and 0.002% B. This has double the yield stress of a similar steel without boron; boron also increases the ultimate tensile strength by about 50% on material normalized at 1750 to 1800° F. If especially ductile sheet materials are required, the steel may be fully annealed by furnace cooling from the normalizing temperature. It may be welded by any normal means. The primary object in develop-

ing such a material was to produce a high-tensile structural steel, with a high elastic limit, good ductility, toughness and workability.

Interesting recent applications based on these properties, together with the good high-temperature strength of the molybdenum steel, are for casings of aircraft jet engines, special tubing and bridge components.

High-Nickel Alloys – "Nimonic 95" has been added to the family of nickel-chromium alloys of that name so widely used for gas turbine blades and other places where severest conditions must be met. (See *Metal Progress* Data Sheet for December 1951.) It is similar to Nimonic 90 – basically a 60-20-20 Ni-Cr-Co alloy – but short-time creep resistance has been improved by increasing the content of precipitation hardeners like titanium and aluminum.

Fig. 2 – Roll Stand of Planetary Mill Installed at Willenhall. Hand points to 2-in. work rolls (not driven) in cage surrounding 20-in. back-up rolls



Produced by Henry Wiggin & Co., Ltd., it is being used experimentally by engine builders. The properties are summarized in Table I on the opposite page.

The older Nimonic alloys 80, 80 A and 90 need a solution treatment of 8 hr. at 1975° F., followed by air cooling. Nimonic 95 is provisionally given a double treatment, first 1 to 2 hr. at 2190° F., air cool, and then 6 to 8 hr. at 1830° F., air cool. All of them are then aged 16 hr. at 1290° F., and air cooled.

Nimonic-clad sheet is another new product. Trademarked "Nimoply 75", it is a metal sandwich made by rolling copper between sheets of Nimonic 75, resulting in a clad sheet having many potential uses, not only for gas turbine construction but also in other fields of high-temperature engineering.

A wrought nickel-molybdenum alloy is also being made in England by this same company. The composition of the favored alloy, "Corronel B", strongly resistant to corrosion, is approximately 66% Ni, 28% Mo and 6% Fe. It can be satisfactorily worked, although it is much stiffer when hot than mild and low-alloy steels. It is said to be highly resistant to hydrochloric acid at all concentrations and temperatures, and has excellent resistance to sulphuric and phosphoric acids in certain ranges of concentration.

FIT FOR A QUEEN

On the occasion of a Platinum Metals Exhibition in London in October last, the Institution of Metallurgists presented to H.R.H. the Duke of Edinburgh for the Queen the unique powder box shown in Fig. 1. This box is made entirely of metals of the platinum group; platinum and palladium predominate, while rhodium, iridium, ruthenium and osmium are used in their normal roles as hardeners. The catch is osmiridium and the mirror on the inside of the cover is of rhodium. One extraordinary feature of the box is the top cover, made from a hard stiff alloy containing 80% platinum and 20% iridium. The delicate work of producing the various motifs involved a thousand individual hand piercing and cutting operations, some of them with saws that were hairlike in thickness.

COPPER AND ITS ALLOYS

Copper is so well established as the material *par excellence* for resisting atmosphere and water that it may come to some readers of *Metal Progress* as a shock to find that numerous instances have been recorded where copper pipe

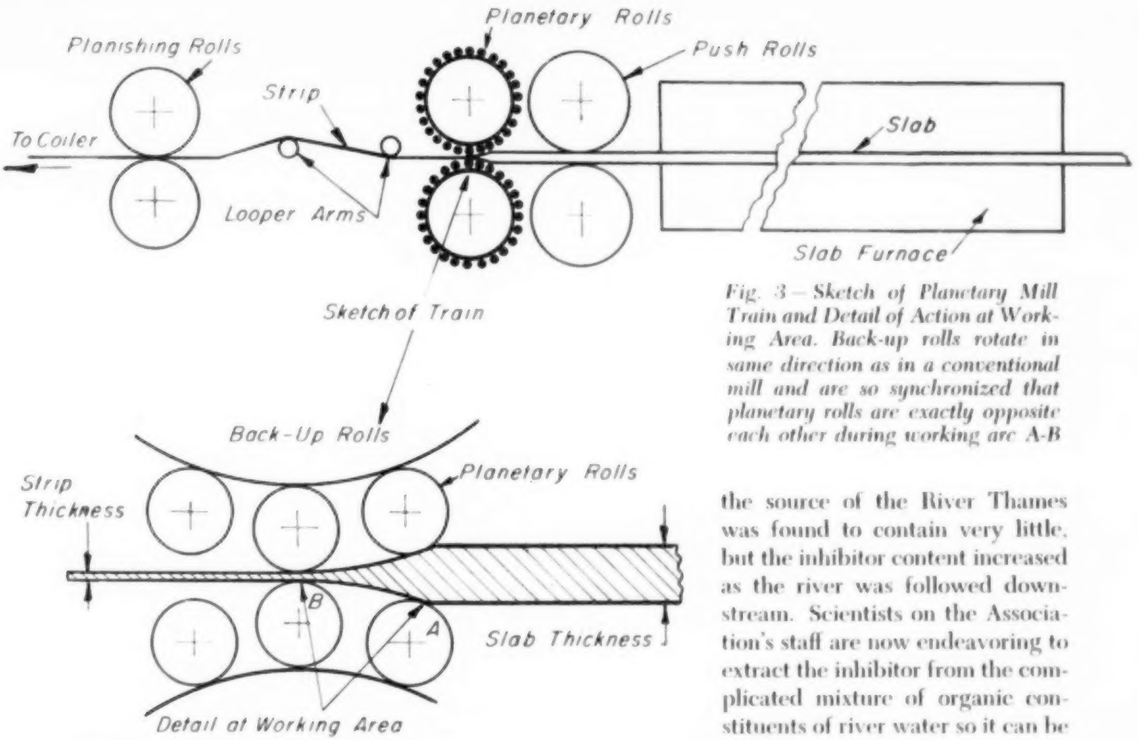


Fig. 3 – Sketch of Planetary Mill Train and Detail of Action at Working Area. Back-up rolls rotate in same direction as in a conventional mill and are so synchronized that planetary rolls are exactly opposite each other during working arc A-B

carrying potable water was penetrated by a pitting type of corrosion. It was similarly disturbing to the staff of British Nonferrous Metals Research Assoc., especially since the occurrences seemed to have no common factor that was not innocuous in innumerable other locations. A first conclusion was that the pits in pipe carrying "hard" water were associated with carbonaceous remains of drawing lubricant, charred during last annealing; some help might therefore be found if the pipe interior were more carefully cleaned. Further study showed that soft moorland waters lay down manganese oxide scales in hot pipes; the scales are cathodic to copper, and sometimes cause pitting corrosion.

In the majority of domestic waters, pitting corrosion of copper does not take place, even in the presence of manganese oxide scales or carbon films, and this is due to a natural inhibitor, organic in nature – or at least this is the conclusion of some metallurgical detective work with a polarograph. Cuprous oxide, normally formed at a corroding copper surface as coarse crystals, is produced in the presence of the inhibitor as a fine-grained film which stifles corrosion. Generally, river waters contain the inhibitor (or give the suspected polarographic indication), but deep well waters do not; spring water at the source of the River Thames was found to contain very little, but the inhibitor content increased as the river was followed downstream. Scientists on the Association's staff are now endeavoring to extract the inhibitor from the complicated mixture of organic constituents of river water so it can be identified.

Cu-Mn-Sn Alloys – Information on a series of copper-manganese-tin alloys (1.5 to 23% Mn, 4 to 14% Sn) has recently been issued by the Tin Research Institute – new alloys which may substitute for nickel-silver or other white metals of good mechanical properties and moderate cost. They can readily be cast, forged, rolled and stamped, and have adequate resistance to ordinary corrosion. Likewise they are satisfactory as a basis metal for the common plating finishes. Heat treatment schedules must be correctly chosen to avoid formation of an unwanted constituent at grain boundaries or along crystallographic planes. Good mechanical properties result from cold working the quenched (solid solution) alloy before tempering.

The mechanical properties appear to be governed primarily by the total manganese-plus-tin

Table I – High-Temperature Properties of Nimonic 95

Temperature °C.	Temperature °F.	Stress to Rupture in 100 Hr.	Minimum Creep Rate for 100 Hr.*
750	1380	49,500 psi.	0.002 to 0.005
815	1500	31,500	0.002 to 0.005
870	1600	20,000	0.002 to 0.005
900	1650	14,500	0.005 to 0.01
925	1700	11,250	0.005 to 0.01

*Percent elongation per hr.

content. It is possible by suitable treatment to obtain ultimate tensile strengths of 67,500 psi. with elongations up to 45%. Tensile strength can be further increased to a maximum of about 90,000 psi. with progressive and fairly rapid fall in the elongation.

The first planetary mill to be installed for commercial use in Europe was demonstrated during the autumn at the works of Ductile Steels, Ltd., Willenhall, England, where it is now being used for the *hot* rolling of low-carbon steel. In this type of mill, most of the work done on the slab is by a series of small work-rolls revolving around a large back-up roll in planetary fashion.

The mill was designed by Sendzimir, Ltd. The planetary assembly (Fig. 2) consists of 26 work-rolls, 2 in. in diameter, equally spaced around a 20-in. back-up roll. Two of these are mounted one on top of another in two-high fashion. Each back-up roll is driven by a 900-hp. motor at a constant speed of 500 rpm., the small work-rolls being free to rotate around the back-up rolls which are completely synchronized with one another. The revolving speed of each 2-in. work-roll is more than 3000 rpm. when in contact with the steel being rolled.

Figure 3 indicates the entire train and also shows an enlargement of the action of planetary rolls on the hot strip. The push rolls, 22 in. in diameter, make an initial reduction and also push the slab through the planetary rolls at a selected speed, according to the gage of the finished strip. Speed is variable from 4.5 to 9 ft. per min. Immediately following the planetary mill, a two-high planishing mill is installed so that a further slight reduction can be made to obtain a flat hot rolled finish. Capacity is in the neighborhood of 10 tons per hr. With the continuous type of furnace, this mill can handle coils up to 15 in. wide of a heavier weight than any other type of hot strip rolling mill. Finished gages vary from 0.187 to 0.040 in. Experience so far has been that sheet from a 30-ft. slab does not vary more than 0.002 in. in thickness, end to end of the resulting coil and across the width of the strip.

It is the intention to roll some low-carbon steel but to concentrate on carbon steels up to 1% for springs and razor blades, stainless steels, and silicon iron. These apparently roll quite easily into very thin gages (that is, down to 0.04 in.).

Automatic Gage Control – The ability to measure changes in gage of the emerging strip with a "roll force meter" opens up new and promising possibilities for automatic control.

This method was first demonstrated on an experimental 10x10-in. two-high mill by British Iron and Steel Research Assoc., wherein the forward tension was used to control the gage in accordance with the information supplied by the roll force meters. In one test a run-down of gage of nearly 0.002 in. on 0.049 in. between 30 and 250 ft. per min. could be expected; with automatic control the entire strip was held to within ± 0.0001 in. at all speeds. The demonstration was repeated on a much larger scale by equipping a 56-in. four-stand cold reduction mill with a similar type of control. It was found possible, even on this scale of operations, to roll consistently at all speeds to far closer tolerances than are otherwise commercially possible.

One of these B.I.S.R.A. load meters of 1350 tons capacity is installed on a tandem mill of John Summers & Sons, Ltd., at Shotton, England. It rests on the upper bearing of the mill and, in turn, the bottom of the screw-down fits into a recess in its upper face. The load-sensitive element between base and top is well protected externally, and consists of a solid cylinder of forged high-tensile steel. Any change in loading causes a corresponding change in height of this cylinder, and this in turn is registered by resistance strain gages attached to its circumference. Such meters of various capacities have been used for years in British mills rolling hot or cold strip.

Wiredrawing – Efficient lubrication of wire in drawing is quite a problem. The thickness of a given lubricant film varies widely in differing conditions. Investigators at the new B.I.S.R.A. Laboratories at Sheffield are studying this film thickness by measuring the electric resistance between die and wire. This resistance is much larger than one would expect if the film were only a few molecules thick. Moreover, it is markedly dependent on speed. In one instance, the resistance increased fivefold from 5 ft. per min. to 50 ft. per min., with peaks exceeding 50 times the minimum! Experiments at speeds prevalent in industry give a similar picture.

Further innovations under study include backpull and cooling techniques. Where at present the speed limit is imposed by a detrimental effect on the properties of the wire, the use of lighter drafts coupled with backpull and aided by effective cooling *before* entry into the die (as well as at the exit from it) seem to offer as great promise as a corresponding use of tension rolls at entrance and exit ends of rolls for cold finishing of sheet. *(Continued on p. 188)*

Titanium in 1953*

Titanium was still scarce in 1953, although the production was substantially increased and additional melting capacity provided. Actual production figures are not available, but the present rate is believed to be about 7½ tons of metal per day compared to 4½ tons per day in 1952. In addition, the 250 tons of sponge in the "revolving stockpile" has been entirely used up. The Office of Defense Mobilization raised the national goal from 22,000 tons per year to 25,000 tons per year by 1956 – about ten times that estimated for 1953. The General Services Administration, successor to this agency, is negotiating with several potential producers to provide for this amount of metal. It is believed that there will be no difficulty in meeting the goal by expansion of production by the Kroll process either in existing plants or by building new ones. Any new processes, however, which may be ready for exploitation on a production scale, will no doubt be given careful consideration.

PRODUCTION OF SPONGE

The Du Pont Co. and the Titanium Metals Corp. of America are as yet the only producers of titanium metal. However, small amounts of high-quality sponge are being made by the Bureau of Mines, and several experimental laboratories operating pilot plants have also marketed small quantities of sponge. The present 1954 goal for both Du Pont and Titanium Metals is 3600 tons each.

Cramet (Crane Co.) has a contract to produce at the rate of 6000 tons per year beginning late 1955 or early 1956. Its plant will be built at Chattanooga, Tenn.; it is expected to cost about $26,000,000 and, in addition to the manufacture of sponge, will include melting facilities for the preparation of ingots. This company will use a modification of the Kroll process developed in its pilot plant in Chicago. Titanium tetrachloride will be prepared from Sorel-type slag (resulting from the reduction of a high-titanium iron ore), and the possibilities of electrolyzing magnesium chloride and recycling magnesium and chlorine are being considered for this step in the process. The plant site at Chattanooga has been cleared and construction of a building to house pilot units has begun. In this pilot operation, to be conducted while the main plant is under construction, full-scale equipment of the kind to be used in the plant will be thoroughly tested to minimize starting-up troubles in the plant itself.

Foreign production of titanium is also increasing. British production, hitherto quite small and of an experimental character, is to be increased to 1500 or 2000 tons per year when Imperial Chemicals Industry completes its new plant. Several Japanese firms are also producing titanium in amounts of 2 to 3 tons per day, and are offering sponge for sale in this country. The quality of this sponge has been checked in several plants and is said to be quite satisfactory.

So far all of the metal produced in the United States has been made by the Kroll process, wherein the tetrachloride is reduced by magnesium in retorts and inert-gas atmosphere. Despite early and repeated prediction of almost immediate obsolescence of the Kroll process, no new process has reached the production stage. However, several new processes have been mentioned or described in the literature. Union Carbide and Carbon Corp. is reported to be negotiating for a production contract and to have a new process. A two-stage reduction of $TiCl_4$ by metallic sodium has been disclosed in a British patent, and an electrolytic process using TiO_2 as a cell feed has been announced. There is also some indication that part of the Japanese production comes from electrolytic processes and part from the Kroll process.

MELTING AND INGOTS

Consumable electrode processes have been developed for melting titanium sponge into ingots. Although the details have not been published, the process is believed to be similar to the methods used for zirconium, wherein the sponge is mixed with the desired amount of alloy constituents, pressed into briquettes or rods, and these welded together to form a bar of the desired size. This bar is then used as the

*Nothing in this article should be construed as representing the official position or view of either the National Academy of Sciences, the National Research Council, or the Minerals and Metals Advisory Board.

By JAMES R. LONG, Staff Metallurgist
Minerals and Metals Advisory Board
Washington, D.C.

consumable electrode; with or without addition of more metal, it is fed into the arc manually or automatically to maintain the arc as the electrode melts off, forming the pool of molten metal which subsequently freezes into the solid ingot. These improvements allow higher current densities and result in deeper molten pools, and hence better mixing of the metal's constituents. These factors have resulted in larger ingots and better control of quality with respect to chemical homogeneity and uniformity of product. Ingot sizes of 1600 to 2000 lb. are being produced and contamination by carbon or tungsten from nonconsumable electrodes avoided. The costs are said to be "low" – presumably meaning cents rather than dollars per pound. Some interest is being shown in double melting procedures in which a small ingot is produced and this remelted as a consumable electrode to produce larger ingots.

The recovery of titanium scrap has received much attention on account of its high value, and the melters have beeen able to use increasing quantities of carefully selected and cleaned home scrap. One company suggests that as much as 30% of the scrap can be readily used. One recovery system consists of mixing small amounts of clean turnings and small scrap with titanium sponge; another uses major amounts of scrap with minor quantities of sponge. Both methods are adapted to consumable electrode melting. Careful control of scrap and sponge metal, both as to amount and as to quality, is necessary to dilute contaminants in the scrap to negligible proportion.

The main problems in the re-use of titanium scrap are, first, its contamination due to pick-up of oxygen and nitrogen during heating for rolling, forging and other working operations, and second, breaking it up into small enough pieces for feeding into the melting equipment. Pieces must be small enough to be melted and mixed in the molten pool without causing the pool to freeze up too rapidly.

The first problem is of minor importance at the present time and is taken care of by careful selection and cleaning of the scrap, and also by using only home mill scrap which can be more readily controlled. As experience is gained and the process brought under control, consumer's scrap will also be used. The second problem is more important. Large pools of molten metal under the arc and means whereby large pieces may be added to the furnace at will have to be perfected. Consumable electrode melting is said to be more readily adapted to use of large scrap than the nonconsumable melting.

Some large scrap is now being melted in induction furnaces and the product scheduled for applications in which carbon pick-up is believed to be unimportant. Skull-melting methods are also being given consideration.

IMPROVEMENT BY ALLOYING

Numerous papers on phase diagrams have appeared in the past year. Most notable is the compilation of data on 48 binary and 22 ternary titanium alloy systems prepared for the Wright Air Development Center*, giving data available up to March 1953. This summarizes the great mass of data on titanium systems accumulated over the last three or four years.

Of major interest was the announcement of weldable alpha titanium alloys containing aluminum and tin. (The insensitivity of titanium-aluminum alloys to heat treatment makes them suitable for applications requiring fusion welding.) These alloys are now undergoing evaluation and may reach the market soon.

Producers of titanium alloys are now able to provide uniform properties and compositions in their products. This results from the availability of sponge of lower hardness, better control over blending of material to be melted, and improved melting methods. Although several attempts were made by a committee of the American Society for Testing Materials to write a satisfactory specification for titanium sponge, agreement could not be reached on residual magnesium and iron and carbon contents. Iron content is of interest in unalloyed metal and recent data indicate that amounts up to 0.25% do not harm tensile properties. Additional information on impact values is being gathered to supplement this work.

There has been a great need for investigations of this kind and their extension to define more clearly the tolerance of titanium (and its alloys) to oxygen and nitrogen. Otherwise, there is no intelligent basis for setting the specification limits for both titanium sponge and titanium products. Although some such work is now going on in various laboratories and it is recognized as a pressing problem, the information so far published is too indefinite to be useful.

With the abandonment of induction melting and wide use of consumable electrode melting methods, carbon content is less of a problem. Magnesium content depends upon the methods

*"Constitution of Titanium Alloy Systems", WADC Technical Report 53-41, February 1953.

used in separating titanium from the reaction products, and the controls exercised on the process. Again, consumable electrode melting may alleviate the magnesium problem.

WELDING AND FABRICATION

Research on fusion welding further delineated the problems in welding of titanium alloys and re-emphasized the need for *complete* protection of the metal during welding. Only commercially pure titanium and alloys consisting entirely of alpha titanium solid solution can now be welded by ordinary fusion techniques. Post-welding heat treatment of alpha-beta type alloys shows considerable possibilities for improving the characteristics of welds in such alloys, but such treatments are not generally applicable to welded structures of any size or intricacy. The deleterious effects of small amounts of nitrogen and moisture in welding atmospheres were demonstrated by several investigators, and this again emphasized the need for complete protection to the metal throughout the welding process. In this connection, successful fabrication of a lot of mortar base plates by welding 0.10-in. sheet, by other than laboratory personnel, is a good indication of the progress that has been made.

Brazing with silver and silver solders was reported to be a satisfactory joining process.

Much progress has been made in fabrication of titanium products. Manufacture of large and small forgings of varying degrees of complexity indicates that many difficulties have been successfully overcome. Several stages of control are necessary; preparation of forging blanks to avoid surface defects, forging temperature, flow of metal in the dies, and controlled cooling from forging temperature are all of importance and require careful attention. Since titanium does not flow as readily as steel, dies should be designed for its special characteristics and its lesser shrinkage (compared to steel). Die finish is also thought to be of great importance.

Heavy plates weighing up to 1000 lb. and up to 2½ in. in thickness, rolled on large plate mills, were reported to roll easier than stainless steels and to have excellent surfaces. Wide strip has been rolled in continuous mills; thin strip up to 8 in. wide and as thin as 0.0005 in. has been rolled in various cluster mills. Excellent results were also reported on the extrusion of titanium shapes and tubes. Several I-beam sections, a large one about 6 in. and a small one about 2 in. high, have been exhibited by producers, indicating progress in this manufactur-

Airframes, Jet Engines Use Output

ing method. Successful aircraft parts made with spinning operations and in commercially pure titanium have also been reported. Tubing from ⅛ in. up to 1½ in. diameter has been made available both in seamless and in welded and drawn varieties.

Improved understanding of the problems in machining and grinding of titanium and its alloys is indicated by the many excellent reports. Of particular interest was the symposium held in March 1953 at Watertown Arsenal, the report of which has just recently been issued.* Although not much data have been given on coolants for machining and grinding, heavy-duty, water-soluble lubricants have given results comparable to those obtained with the gaseous refrigerant, CO_2.

CURRENT APPLICATIONS

No outstanding new applications for titanium and its alloys have been reported during 1953, but some of those previously given much publicity are reaching the stage of production and use. Of special interest are several airframe parts or subassemblies. Here the emphasis is on the unalloyed metal because of its availability in sheet form, ease of fabrication, and weldability. However, some alloy ribs are used for stiffeners and higher stressed parts. The new DC-7 has nacelles and firewalls of titanium, resulting in a saving of about 300 lb. in weight. When titanium was substituted for stainless steels on a gage-for-gage basis no serious fabricating difficulties were encountered, and all of the nacelles for the DC-7 planes are expected to be made of titanium.

The jet plane, FJ-2, has been cited as an excellent example of the applicability of the metal to jet planes. It is used in fuselage, bulkhead, shroud assemblies, ammunition tracks, and flap rubbing strips, again substituting for heavier stainless steel. Up to 600 lb. of titanium is reported to be used in production models of jet planes, including sheet, bar stock, and forgings.

The greatest use for titanium, however, is for the compressor disks and blading, and although these are the widely mentioned parts, many other jet engine parts are under investigation and trial. In all likelihood, jet engines alone could readily use the entire projected titanium production in 1956.

*"Proceedings of the Symposium on Machining and Grinding Titanium", Watertown Arsenal, Watertown, Mass., March 31, 1953.

New Manufacturing Processes for High-Grade Steel in Sweden

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HISTORICALLY, the rather unusual development of steelmaking in Sweden ought to be viewed against the special conditions which have prevailed in this country. In ancient times Sweden had a very favorable position as to raw material supplies. The resources of good magnetite and hematite ores, either low or high in phosphorus, were at that time considerable – as indeed is true today.

However, only a small proportion of the ores which are mined will be utilized within the country. An important (and recently greatly increased) export has been built up, mainly of ores high in phosphorus from the vast deposits at Kiruna in the north and Grängesberg in the central part of Sweden. Export from these and other mines amounted in 1952 to about 17 million short tons.

Our vast forests have been another valuable asset for the iron and steel industry, especially as long as the ironmakers were forced to use charcoal as reducing agent for the production of a sufficiently clean pig iron. The almost complete lack of fossil coals in Sweden caused no trouble at that time. Our large resources of water power have always been important.

As a consequence, Sweden in ancient times was the leading iron producer of the world. In 1740, for instance, Swedish production amounted to not less than 40% of the world's.

The Swedish hegemony was, however, rapidly lost at the end of the 18th century when good steel was made out of coke pig iron via the puddling process (wrought iron) and the cementation process. The rapidly increasing industrial demand for commercial iron (and steel) could then be supplied without basing the production on charcoal, and steelworks of quite different size than the old Swedish plants were erected in other countries.

The manufacture of low-phosphorus steel was, moreover, much facilitated later on by the introduction of the basic processes (bessemer and Siemens-Martin) in about 1880. Swedish predominance in the "fine steel" industry lasted, however, for some decades after 1880 until it really became possible for the product of the new steelmaking methods to compete with the Swedish high-grade steel based on charcoal pig iron. (Steel refining in Sweden at the turn of the present century was principally by the reliable acid steel processes, but some was also made by different wrought iron processes.)

In the early 1900's, however, the electric steel methods were invented and commercialized, in which a steel of high purity could be made independent of the raw material's quality. Foreign competition for the Swedish steel industry then began to be really serious. Economic dislocations due to the two world wars have also disrupted the export situation to a high degree. Nevertheless, it has been possible to keep the export trade alive and, today, it is on a not insignificant level, but this has required continuous and tenacious research directed toward the improvement of quality and uniformity. Concurrently, a considerable concentration and rationalization of the industry have been necessary in order to meet competitive costs. Of great value in both respects has been the extensive joint research work that was started in 1926 by Jernkontoret (the Swedish Iron Masters' Assoc.) and which is still very actively pursued.

While it has thus been possible to maintain a considerable export business in high-grade steels, it has proved far more difficult to compete with other countries in the production of commercial steels – that is, carbon steel products like sheet, wire, plates, bars, structural shapes. A great deal of such steel has had to be imported, especially since 1930, in order to fill our own largely increased demand.

Statistically, the situation in Sweden since 1900 has been about as follows:

Annual exports of finished steel held fairly steady at a figure of a little less than 200,000 short tons from 1900 to 1917, when a rapid decline occurred, reaching a minimum of 70,000 tons in 1921. Exports then gradually recovered to a top of 220,000 tons in 1941, when another wartime decline occurred to about 90,000 tons in 1944. Since then exports have again increased steadily to about 170,000 tons (1952). This is not a true measure of the *value*, since much of this is highly finished material commanding a substantial price.

These figures do not bulk very large in comparison with our total production, which, as can be seen in Fig. 1, rose steadily from the post-World-War I low of 260,000 ingot tons to about 1,800,000 ingot tons in 1952. Total consumption in Sweden has also grown at a similar high rate, reaching about 1,900,000 short tons in 1952. Through the years about 60% of this has been supplied by our own steel mills and 40% by imports. A large program of expansion is now under way which will enlarge Sweden's total production to about 2,200,000 short tons of ingots, and this is expected to lower considerably the proportionate amount of imports.

In the following article high-grade steels will be discussed to the practical exclusion of the commercial steels, although no line really can be drawn between them, and to a great extent the same methods and furnaces are used. Trends in production of different types of pig iron and sponge iron since 1900 are shown in Fig. 1 and trends in the various types of steelmaking processes in Fig. 2.

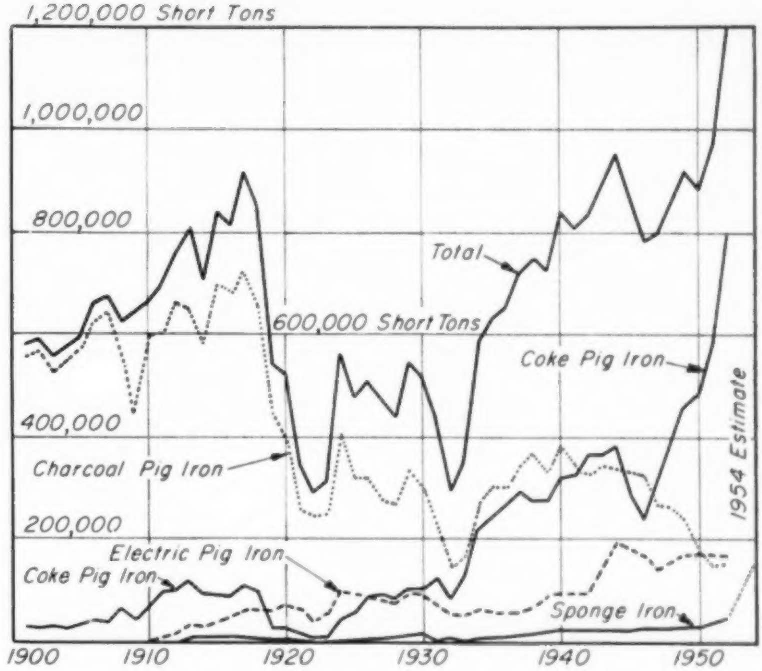
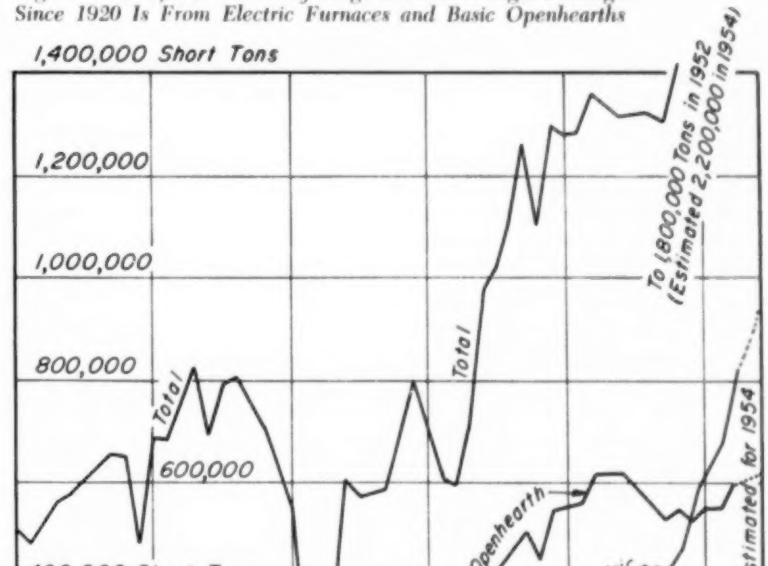


Fig. 1 – Statistics of Swedish Iron Production Show Large Drop in Charcoal Pig Immediately After World War I, and Important Rise in Coke Pig Since 1930

Fig. 2 – Most of Sweden's Very Large Increase in Ingot Tonnage Since 1920 Is From Electric Furnaces and Basic Openhearths



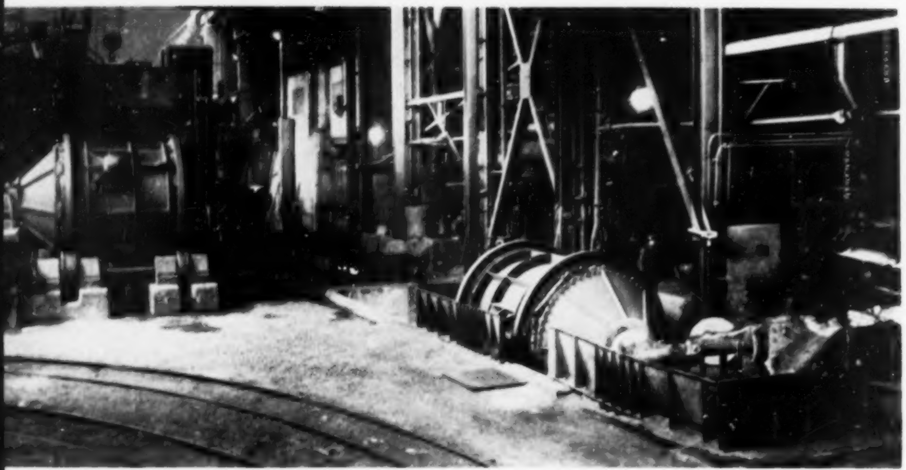


Fig. 3 – Two Rotating Kilns Used for Desulphurization of Molten Pig Iron by Tumbling It With Pulverized Lime. No liquid slag is produced. Sulphur may be driven below 0.010%

RAW MATERIALS

Pig iron production up to the last 20 years has been based principally on charcoal as reducing agent – mainly in blast furnaces, and to a lesser extent in electric shaft furnaces of the Swedish Elektrometall type. The Swedish charcoal blast furnaces have a comparatively low capacity, seldom exceeding 100 short tons of pig iron a day.

On account of the great increase in charcoal price during recent years (partly due to the increase in wages and partly to the competition from the paper pulp industry), it has been necessary to find another reducing agent – even for pig iron destined for the high-grade steels. Charcoal pig iron might readily be replaced with coke pig iron, but this has been done with great caution as the possibility existed that the latter would contain unanalyzed elements having a harmful effect on the steel's quality. Careful investigation, however, at several high-quality steelworks has proved that coke pig iron can be used with advantage for most steels if the sulphur and phosphorus contents are low enough for the acid steel processes.

Low-Phosphorus Pig – In order to obtain a pig iron with sufficiently low content of phosphorus it is first of all necessary to smelt ores low in phosphorus. This requirement is comparatively easily fulfilled in Sweden, as low-phosphorus concentrates can be obtained from a great many ores from central Sweden. An inexpensive method for purifying a concentrate to especially low phosphorus content has been worked out at Grängesberg, wherein the concentrate is leached with nitric acid in a rotating barrel. Furthermore, we have lowered the phosphorus content in the pig iron, limiting the content of phosphorus in the purchased coke. It is of course also important to try to reduce impurities coming from the fuel by reducing the coke consumption down to the minimum.

By a combination of these efforts coke pig iron in blast furnaces is now produced in Sweden with phosphorus contents of 0.020 to 0.025%.

The Sulphur Problem – Sulphur can only with great difficulty be cut to the level required for acid steel production, so several steelworks desulphurize the pig iron outside the blast furnace. Some works have adopted the method developed at Domnarvet, whereby the molten iron is treated with pulverized burnt lime in a rapidly rotating kiln (Fig. 3) – which is also transportable so it can be mounted on a car and used as a transport ladle. In this way there is no difficulty whatsoever in reducing the sulphur content of the pig iron to well below 0.010%, even though it initially is very high.

Sintering – The very high cost of fuel has forced us in Sweden to prepare the blast furnace charge so it can be most reducible. The general procedure is to fine-grind the ore, concentrate it to a low gangue content, mix with necessary flux and cheapest fuel, and finally sinter the concentrate. The first sintering plant was put into use in Sweden in 1925; nowadays more than 90% of the ore is sintered. Thus, only a self-fluxing product is eventually charged to the blast furnace.

Conventional sintering equipment, such as the Greenawalt design, is usual, although the pelletizing process has recently attracted attention and some use.

Electric Furnace Iron – From Fig. 1 it can be seen that about 170,000 short tons of pig iron has been made annually in electric furnaces for the last 10 years. The old Elektrometall design has been abandoned because it required charcoal for a reducing agent. Present production is from the so-called Tysland-Hole type of low-shaft furnace, designed by the Norwegian firm Elektrokemisk. Further expansion of elec-

tric iron, in competition with blast furnace pig, will depend on the cost of blast furnace coke in relation to the cost of heat from electric power.

(A cross section of the Tysland-Hole furnace, using three vertical electrodes, is shown on p. 85.)

Sponge Iron – Prior to the last war, most of the Swedish sponge iron was reduced by coke or charcoal breeze in crucibles or muffles from especially pure iron or concentrates (the Sieurin-Höganäs process) and a great part of this has been exported for use in powder metallurgical products. This is still an important item of commerce, but it can be seen by Fig. 1 that a very large increase in tonnage of sponge iron is expected next year. Most of it will be retained in Sweden and converted into high-quality steel.

One may ask why our interest in sponge iron is so great, whereas this raw material is made only very sporadically in other countries and in very small quantities. The reason is that the product is a clean iron with extremely low content of sulphur as well as phosphorus, a very suitable raw material for high-grade steel. Previously, we considered the low carbon content of special value, the pig iron proportion in the openhearth charge being very high. At present, however, it is not always of advantage, since the sponge iron will replace so much pig iron that a high carbon content would sometimes be more desirable.

The natural conditions for sponge iron production in Sweden are also very good. Our rich ores constitute a suitable raw material and the processes can be carried out with very good fuel economy – always an important factor in a country which imports all its requirements for coal, coke and fuel oil.

Most of the new production of sponge iron will be by the Wiberg-Söderfors process, which has been so often described that it is unnecessary to repeat here. (See, for example, *Metal Progress* for May 1950, p. 633.)

The first commercial Wiberg-Söderfors plant has been in operation at Söderfors for about 10 years. It has been succeeded by three other installations, and one more is being erected. When all these plants are running with full capacity next year, the total sponge iron tonnage in Sweden will amount to about 210,000 short tons annually, of which 145,000 tons will come from the Wiberg-Söderfors process. This quantity may not seem very impressive, but sponge iron will in the future form an important part of the raw material base for the Swedish high-grade steel industry.

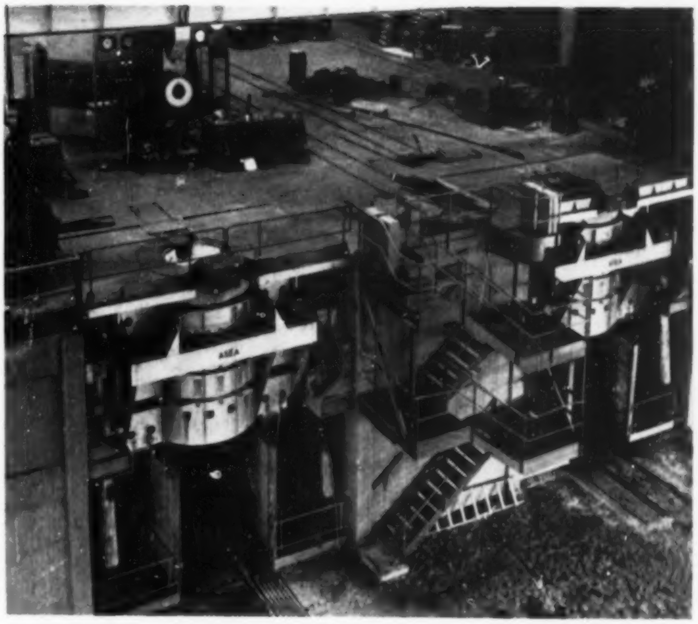


Fig. 4 – Tandem Induction Furnaces, 12-Ton Capacity, for Manufacturing High-Grade Steel, Installed at Bofors plant

STEELMAKING

Statistics since 1900 for steel production in Sweden according to different processes are shown in Fig. 2. The acid steel processes superseded the old methods based on wrought iron just before the turn of the century. Acid steel might be said to keep this favored position today, even though the term "high-grade steel" represents a narrower field than previously.

Of course, an important tonnage is nowadays made in electric furnaces, and of our total basic openhearth production a large part could be designated as "high-grade". (No distinction as to quality has been made in Fig. 2.) The acid processes, however, are used only for high-grade steel, while basic *bessemer* produces commercial steel only.

As has been indicated in the foregoing part of this article, the most important raw materials for our quality steel production are charcoal or coke pig iron low in sulphur and phosphorus,

(Continued on p. 200)

Postwar European Progress in Wrought Aluminum and Its Alloys

At the end of World War II primary aluminum production declined sharply in Europe (as it did everywhere in the world) since the re-establishment of a peacetime economy required some time. A large proportion of the aluminum had been used for aircraft and ordnance; new applications had to be found for the metal from the new pot lines. Moreover, Germany dropped out completely immediately after the war because production of primary aluminum was forbidden by the Allies. A summary of the statistics follows, showing that wartime records have now been surpassed. In 1952 European aluminum production amounted to somewhat more than half that of the U.S.

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Production of Primary Aluminum, Short Tons

Year	Europe	U. S.	World
1936	25,000	12,000	40,000
1940	43,000	22,000	87,000
1943 (max.)	48,000	91,000	215,000
1946 (min.)	12,000	40,000	88,000
1952	50,000	95,000	233,000

Scrap Recovery – A prime question ten years ago was how to recover and re-use the large amounts of wartime scrap. Remelting methods were considerably perfected to such a point that the "secondary" aluminum alloys are equivalent in their properties to those produced from primary aluminum, assuming the same chemical composition. Scrap has, therefore, become an important raw material for semifinished products and castings, as it has been traditionally in the steel industry.

The Melting and Casting of Aluminum Ingots –Whereas before and during the War electric furnaces were favored by Europeans for melting aluminum and aluminum alloys, gas or oil-fired furnaces are now more and more acceptable on the grounds of industrial economy. However, for high-quality requirements, low-frequency induction furnaces are preferred because an exceptionally oxide-free melt is obtained with low consumption of fluxing materials; furthermore, a thorough mixing of the melting stock is also obtained from the agitation induced by the current. Coreless induction furnaces for line frequencies (say, 60 cycles) have been used for melting down turnings in rammed crucibles, and for the production of master alloys.

Approved furnace combinations consist of low-frequency furnaces for melting; metal is transferred by runners into resistance-heated holding furnaces where it is held until poured. Continuous or semicontinuous casting (which corresponds to the American "DC-Process") had been developed in Germany before the War. This process has recently been extended, in particular to equipment for simultaneous casting of up to 16 billets (multiple poured). The metal supply to the individual molds is controlled either by hand-regulated nozzles or by automatic floats.

Further progress has been made in the casting of hollow billets, 7 to 30 in. diameter, 1½ to 5-in. wall, for the production of tubes, and in the casting of clad ingots in which the central metal is poured between the plates of cladding by a semicontinuous method. This process produces much less scrap than the usual method of rolling a stack of plates.

The "Properzi" process for the fully continuous casting and rolling of small rods was developed in Italy. In this process the metal is poured on a groove in the rim of a revolving wheel, this groove being temporarily covered by a steel strap. As the wheel revolves the metal solidifies, and at the proper place both steel cover and continuously cast rod are peeled off, the latter being sent to a continuous rolling mill. Machines of this type have been used successfully for producing commercially pure aluminum wire.

Aluminum-magnesium alloys have special interest among the nonaging materials, since they are distinguished by good corrosion resistance and by the fact that their mechanical properties are preserved even across welded joints. During the War, alloys of up to 9% Mg were utilized in Germany, even though it was known that alloys with such high magnesium were inclined to intercrystalline corrosion and stress-corrosion. For example, rivets made of a 5% Mg alloy, used in the hulls of English flying boats, cracked in the tropics. Stress-corrosion was the culprit.

Stabilization Heat Treatments – Intensive investigations carried out during and after the War showed that the susceptibility to intercrystalline corrosion of these alloys is related to their microstructure – and is especially marked when grain boundary precipitation of the beta phase forms a continuous network. To avoid this critical microstructural condition with certainty a heat treating method was devised which consists of an adequate slow cooling at about 100° F. per hr. from the homogenization temperature. By this "stabilization" all the magnesium in excess of the solubility limit at room temperature is precipitated and a more homogeneous form of precipitate is obtained, both inside the grains and a coagulation of the particles at the grain boundaries. Precipitation is further promoted by an addition of about 0.2% chromium. This microstructure is unaltered by reheating to 300° F. so that "stabilized" material may be considered as being immune to intercrystalline or stress-corrosion. Much practical experience also shows that the danger of intercrystalline corrosion and stress-corrosion is efficiently counteracted, even with alloys greatly supersaturated with magnesium. This has extended the European use of these alloys to a much broader basis.

A special heat treatment is also used for aluminum-magnesium-silicon alloys with 1.0 to

Table I – Properties of Al-Zn-Mg Alloys Used in Germany

Designation	Chemical Composition*					Minimum Values‡			Maximum Values‡		
	Zn	Mg	Mn	Cr	Cu	Ultimate	Yield	Elong.	Ultimate	Yield	Elong.
Constructal 20/42	4.5	2.5	0.6	–	0.1	65	51	10%	71	60	12%
Constructal 20/53	5.0	3.0	0.8	0.3 max.	0.1	71	64	8	77	68	8
Hy 43	4.5	3.5	0.3	0.1 max.†	0.4	71	64	8	77	68	8

*All alloys have 0.4 Si and O.S. Fe †Plus 0.2 to 0.6 V
‡Ultimate and yield in 1000 psi.; all values for samples age hardened 48 hr. at 100°C.

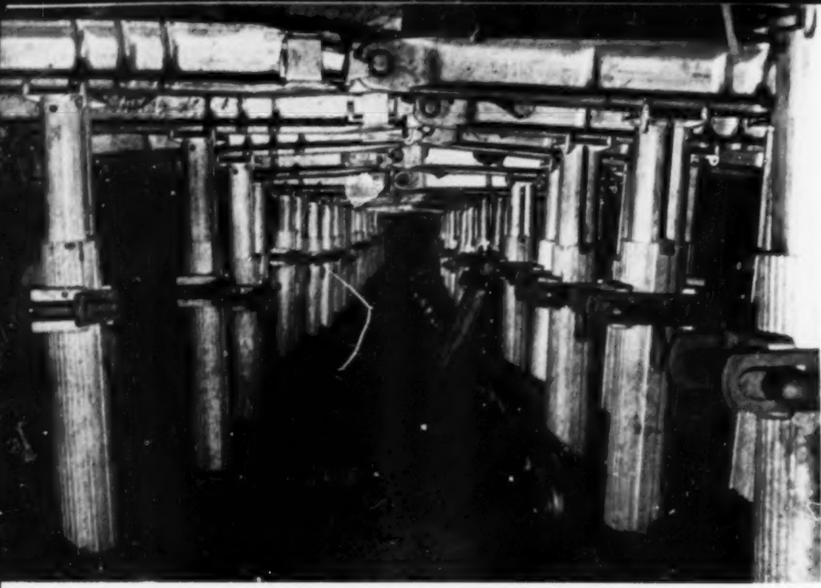

Fig. 1 – Aluminum Caps and Props in Coal Mines Are 40% as Heavy as Steel, and Have High Resistance to Sparking and to Corrosive Waters

1.4% Mg and 0.8 to 1.2% Si. It consists of a solution heat treatment at 1000° F., a water quench, and an immediate age hardening at 300° F. for 24 to 48 hr. By avoiding storage at room temperature between quenching and age hardening, tensile strength of sections can be increased to 45,000 to 57,000 psi., yield point to 37,000 to 50,000 with elongations of 16 to 6%. These alloys are preferably used for structural parts in vehicles, bridges and other superstructures. In order to guarantee corrosion resistance, the permissible copper content is held at a low value–for example, 0.05% for ship structures.

Aluminum-zinc-magnesium alloys have lately acquired increased significance. During the War they were much used in German aircraft – indeed preferably for extruded sections and forgings which carried high design stresses. When these alloys were first introduced in Germany in 1920, they created a metallurgical sensation because their tensile strength surpassed that of duralumin (Al-Cu-Mg). However, many applications failed because of stress-corrosion. After the Al-Zn-Mg alloys fell into near oblivion for 15 years, the problem of stress-corrosion in these alloys was tackled systematically from various sides and a practical solution was found.

Aside from production methods, especially the introduction of continuous casting, the following innovations are noteworthy.

1. Special heat treatment. Cooling rate after solution heat treatment is considerably lower than that of water quenching. The optimum method is to cool in stages by using an intermediate bath (a molten mixture of nitrate and nitrite salts at 350° F.). Interrupted quenching has also found favor for decreasing the internal stresses in heavy extruded sections and forgings.

2. Additions of "stabilizers", such as chromium and vanadium.

Both these methods should be combined to obtain optimum mechanical properties, and to avoid danger of stress-corrosion.

The Al-Zn-Mg alloys used in Germany during the War are shown in Table I. Similar alloys introduced by Aluminum Co. of America have about 1.5% copper and do not use the special heat treatment outlined above. The tensile strengths of the American alloys (notably 75 S) are somewhat higher than the alloys listed in Table I – admittedly at the expense of corrosion resistance.

A further increase in tensile strength was attained after the War by increasing the zinc content up to 8%, as in the French alloy "Zicral". (Alcoa has brought out a similar alloy designated as 78 S.) Tensile strength of up to 110,000 psi. and yield points up to 105,000 psi. were achieved by extruded rods of such an alloy, and elongation still amounted to 5%. Materials of this type are very notch-sensitive, which fact is to be given careful consideration not only by engineers and designers (no notches or sudden changes in section) but also by workmen (avoiding surface damage). After the War extruded semifinished products and forgings of such alloys were introduced for the first time for high-quality structural parts for French jet aircraft.

As in the United States, plates and strip of copper-containing Al-Zn-Mg alloys are clad with a layer of zinc-bearing aluminum to provide corrosion resistance.

Various copper-free Al-Zn-Mg alloys are used for semifinished products which cannot be clad or plated. These alloys have higher corrosion resistance than alloys of a similar type but containing copper.

Alloys with low zinc and magnesium (for example, 4 to 5% Zn and 1% Mg) are also sufficiently resistant to stress-corrosion without the use of "stabilizers" or some special heat treatment. These alloys are distinguished not only by good weldability, but also reach higher tensile values in the welded state than other age hardening alloys, because a significant hardening occurs during cooling from the welding temperature. Probably greater attention will be given in the future to these alloys for welded

members bearing high design stresses. These alloys are also very well suited for applications using anodic protection.

ALLOYS FOR SPECIAL USES

Machinability – A series of special materials worth mentioning is the free-cutting alloys of aluminum. Because their price is lower than that of brass they have been accepted during the postwar period in some important fields of application. Chip-breaking additions of lead, bismuth, zinc or cadmium have been used. The most common alloy is a duralumin type with 1 to 2% lead, but other alloys (especially Al-Mg-Si, Al-Zn-Mg and Al-Zn-Mg-Cu) are also in use depending on the requirements set for machinability, tensile strength, corrosion resistance and anodizing capacity.

Bearings – The work carried out during the War in the field of aluminum bearing alloys has been resumed. The aluminum alloys, as compared to the conventional bearing alloys such as leaded bronzes and babbitts, have the advantages of lower weight, higher load-carrying ability and greater resistance to fatigue and wear. They have varying but substantial additions of zinc, lead, tin and antimony, depending on their application. Journal bearings are mostly made out of laminated material – indeed the relatively soft aluminum alloys are frequently only a thin layer or plate on a supporting shell of a high-strength aluminum alloy or steel. This type of thin-wall bearing is chiefly used in gas engines (for example, the main bearings in the motors for German Volkswagen) where they have proved to be excellent.

High-Purity Metal – Since the War, superpure aluminum (99.99%) has been produced on a considerable scale in some European countries by the three-layer electrolytic process. The price of such aluminum can therefore be lowered since secondary aluminum contaminated with copper is used rather than virgin aluminum. Since such high-purity aluminum is too soft for many purposes, a series of aluminum alloys has been developed on a high-purity aluminum base, in particular by the addition of magnesium. These alloys, designated as "Reflectal", lend themselves to mechanical, chemical or electrochemical polishing and are used for reflectors, hotel and hospital utensils, ornamental trim on automobiles and buses, as well as for useful household objects of all types. A large part of the high-purity alloys is used in the form of sheet, strip, rods, wire and other semi-finished products by the jewelry industry, wherein the finished articles are anodized and colored. Arm bands, neck chains, broaches, cigarette boxes and cuff links enjoy particular popularity. Although they are very cheap, the gold-finished articles can barely be distinguished in color and luster from genuine gold. The wear resistance and stability of this alloy insure great durability.

JOINING PROCESSES

While much study has been given to welding and brazing processes, no noteworthy practices other than those commonly used in the other industrialized parts of the world have received engineering and commercial approval. The "cold welding" process developed after the War is not commonly used. It is possible to weld together high-purity aluminum and certain aluminum alloys without the use of heat, but the practicability of such a process is limited to those places where much cold working of the part can be tolerated (corresponding to a reduction in cross section of around 50%).

Resin Bonding – One apparent exception to the statement that joining practices are relatively static is that the use of a synthetic resin as a "glue" has resulted in remarkably strong and durable joints. These methods are especially well suited for the age hardenable, high-strength

(*Continued on p. 194*)

Fig. 2 – Aluminum Bascule Bridge at Aberdeen, Scotland

Metallic Materials for a Steam Power Plant Operating at 1130° F.

By HERBERT BUCHHOLTZ, WILHELM RUTTMANN and RUDOLF SCHINN*

In November 1951 the Bayer Farben Fabrik A.G. (Bayer Dye Works) installed a steam power plant operating at 160 atmospheres pressure and a steam temperature of 1130° F. (610° C.) at Leverkusen, Germany. The steam boiler (Benson) was supplied by Dürrwerke at Ratingen, the simple radial turbine by the Siemens-Schuckertwerke A.G. at Mühlheim, Ruhr, the boiler tubes and pipe system principally by the Deutsche Mannesmannröhren-Werke A. G., Düsseldorf. Since this plant has now operated 10,000 hr. without mishap, it seems appropriate to make a complete report on the materials used in its construction. Exhaustive reports on the planning, design, and construction have already been presented to the V.D.I. meeting in Essen on May 18, 1953 by H. Tietz, H. Buchholtz, M. Werner, W. Ruttmann and R. Schinn and published in *Zeitschrift des Vereins Deutscher Ingenieure*, Vol. 95, 1953, p. 801. However, it seems desirable to summarize for metallurgists the important points concerning the materials which were actually selected for use.

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Steels Used – A thermodynamically significant jump to higher steam temperatures in steam power plant design is attended by an increase in pressure, and therefore an increase in stresses carried by the materials of construction. The strength of ferritic steels commonly used for steam power plants operating at 930° F. (500° C.) drops abruptly at 975° F. or thereabouts. Moreover, the scale formed at these high temperatures is no longer protective against further oxidation. Increasing the chromium content of the steel above 5% prevents the scale from sloughing off, but acts so as to

Table I – Materials for Carrying Superheated Steam

Number	Uses	Chemical Composition						
		Carbon	Silicon	Manganese	Chromium	Nickel	Molyb.	Others
				Ferritic Steels				
I	Boiler tubes	0.15%	0.25%	0.65%	—	—	0.30%	—
II	Turbine housing	0.20	0.40	0.60	0.10%	—	0.60	—
III	Superheater tubes	0.13	0.25	0.55	0.85	—	0.45	—
IV	Turbine shaft	0.25	0.30	0.50	1.40	0.50%	0.60	0.2% V
V	Intermediate stage wheel	0.19	1.00	0.40	1.40	0.30	1.00	0.5% V
VI	High-pressure wheel	0.20	0.30	0.40	13.6	0.40	1.00	—
				Austenitic Alloys				
VII	Fittings and supports	0.07	0.40	0.40	12.5	12.0	—	—
VIII	Superheater tubes, fittings	0.06	0.70	1.20	16.5	13.0	—	0.6% Cb
IX	Valve bodies	0.06	0.70	0.80	17.0	13.0	—	0.6% Cb
X	High-pressure buckets	0.07	0.80	1.20	16.5	14.0	2.0	1.2 Cb, 0.15 N
XI	Safety valves	0.07	1.00	1.30	16.0	21.5	1.3	1.0 Cb, 0.8 V, 0.12 N
XII	Valve stems; bolts	0.05	0.90	0.60	16.0	35.0	4.7	1.7 Ti, 4.8 W, 23.0 Co

decrease the strength of the steel itself.

Any pressure system operating at 1100° F. and above therefore requires some important departures from conventional "high-pressure" installations. The most important materials for steam systems in the present power plant are listed in Table I. The amount of austenitic steels was kept to an irreducible minimum for reasons of economy and because we lack experience with them in long-time operation. Some of the properties of the austenitic steels had to be carefully considered in their relation to the construction of the parts that came in contact with hot steam.

Thermal stresses in a structural material are proportional to the coefficient of thermal expansion. As is indicated in Table II on p. 118, austenitic steels have a higher coefficient, and 13% chromium steels have a somewhat lower coefficient than ordinary ferritic, low-alloy steels over the entire temperature range. Again, the magnitude of the temperature difference causing a thermal stress depends upon the thermal conductivity and the wall thickness. In this respect the thermal conductivity of austenite is definitely poorer than that of medium-alloy steels at low temperatures, although the difference is smaller at the operating temperature (1130° F.). Consequently austenitic steels must endure considerably heavier thermal stresses due to temperature change than would their ferritic counterparts. If this is overlooked by the designers the austenitic steels are prone to such damage as shown in Fig. 1. The wall thickness of a valve for reducing pressure of steam from 160 to 30 atmospheres was 3.35 in., which was thicker than actually required by calculations based on internal pressure. The steep thermal gradients developed in continuous opening and closing of the valve (in conjunction with corrosion) led to the transgranular cracks shown in Fig. 1 that penetrated as deep as 1⅛ in.

Creep Strength – Short-time tensile tests are of limited value and only for judging the dimensional behavior of parts operating above 1000° F. in the plastic or semi-plastic range. Since there was only scattered information about practical experience or real long-time tests on austenitic alloys at 1100° F. and higher, participating contractors conducted many creep tests with a large number of steels. The stress for 0.1% and the 1% strain and the rupture stress were read from creep curves lasting at least 10,000 hr. and extrapolated to 100,000 hr.

For dimensioning the moving parts of the turbine, the elongation after 100,000 hr. permissible by the design was determined. Steels and alloys meeting this requirement also had to have sufficient rupture strength. Higher permanent elongations after 100,000 hr. (up to 1%) were allowed in the statically stressed parts of the boiler and steam conduits.

Figure 2 shows the long-time rupture strength (at 100,000 hr.), the long-time yield strength (1% at 100,000 hr.) and the DVM creep rate up to 600° C. (1110° F.) for the standard superheater steel No. III of Table I. In the range of 500 to 550° C. (925 to 1020° F.) the creep strength drops abruptly about two thirds. On the basis of strength (let alone scale resistance) the Cr-Mo steel No. III must definitely offer a limited service life at 550° C.

The solid curve in color in Fig. 2 gives the allowable or design stress for wall thickness. Up to 500° C. it is calculated as a minimum of 1.5 safety factor based on creep rate. Above

Table I – Materials for Carrying Superheated Steam

Fabrication History	Mechanical Properties					
	Yield	Ultimate	Elongation*	Reduction	Impact†	Number
			Ferritic Steels			
Rolled, normalized	45,500 psi.	71,000 psi.	26%	60%	—	I
Cast, air cooled (a.c.)	47,000	74,000	26	52	7	II
Rolled and drawn, a.c.	50,000	74,000	26	60	—	III
Forged, oil quenched	102,000	120,000	15	45	8	IV
Forged, oil quenched	100,000	124,000	19	60	7	V
Forged, oil quenched	88,000	118,000	19	56	7	VI
			Austenitic Alloys			
Rolled, heat treated (h.t.)	28,500	71,000	55	50	—	VII
Forged or cold drawn, h.t.	42,500	78,000	45	30	15	VIII
Cast, air cooled	34,000	71,000	35	34	6	IX
Warm-cold forged, annealed	82,500	108,000	25	55	13	X
Forged, heat treated	47,000	89,500	40	55	10	XI
Rolled, annealed	74,000	125,000	40	40	13	XII

*In 5 diameters gage. †In kg-m. per sq. cm.

Fig. 1 – Slice Taken From Valve Body; Internal Diameter 6.30 In.; Wall Thickness 3.35 In.; Material: 17-13 Cr-Ni Alloy No. VIII of Table I. Valve reduces steam pressure from 160 to 30 atmospheres; cracks are due to fluctuating thermal stresses plus corrosion

500° C. it equals the long-time yield strength at 100,000 hr., or the long-time tensile strength after 100,000 hr. with a safety factor of 1.5, whichever gives the smaller value. This steel was used for superheater tubes, condensers and conduits with a steam temperature of 530° C. (985° F.) and lower.

The allowable stresses for the stabilized austenitic steel No. III of Table I, used for all boiler parts, condenser parts, fittings, and pipes exposed to steam temperatures above 530° C. are given in Fig. 2 as a dotted line in color along with the data for the Cr-Mo steel for comparison's sake.

Safety at High Temperature – A comparison of the insurance offered by the two types against rupture as the temperature increases is interesting. With an allowable stress of 5250 psi. (3.7 kg. per sq. mm.) Cr-Mo steel No. III, according to Fig. 2, can go to about 550° C. (point A in Fig. 2, or 1025° F.) while the austenitic steel No. VIII can be used to 650° C. (point B, or 1200° F.). Under these conditions other data would show that the Cr-Mo steel would break after 370,000 hr. and the austenitic after 500,000. The safety factors are then 3.7 and 5 respectively.

Failure after 100,000 hr. will occur if the Cr-Mo steel overheats from 550° C. to 565° C. (that is, only 15° C.), whereas failure in 100,000 hr. will not occur in the austenitic steel until the temperature has climbed from 650° C. up to 720° C. – a margin of 70° C. Consequently, the safety against overheating in the temperature range which is critical is much larger for austentic Cr-Ni steel No. VIII than for the Cr-Mo steel No. III.

The wall thicknesses for boiler parts and conduits were figured from internal pressure by the following formula:

$$t = D \div \left(\frac{200S}{Pk} + 1\right)$$

where t = wall thickness
D = outside diameter
S = allowable stress according to Fig. 2
k = factor to allow for nonuniform stress distribution throughout a thick wall
P = internal pressure

For a superheater tube with operating temperature of 650° C. (1200° F.) a minimum wall thickness was calculated for a 25.5-mm. (1-in.) outside diameter of 5.0 + 5% tolerance = 5.25 mm. (0.200 in.), that is, with an inside diameter of 15 mm. (0.60 in.).

For the hot steam piping with 610° C. operating temperature (1130° F.) and an outside diameter of 63.5 mm. (2.5 in.), the minimum wall thickness calculated to be 10.2 mm. plus tolerance of 1.8. This totaled to 12 mm. (0.47 in.) thick, which gave an inside diameter of 39.5 mm. (1.55 in.).

Toughness – It was necessary to prove whether these new austenitic steels acquired brittleness in high-temperature installations even though they may have started out with sufficient toughness.

The high impact energy of simple austenitic steels at room temperature is well known. Complex austenites with good high-temperature

Table II – Thermal Constants (c.g.s. Units) for Typical Metals

	Low-Alloy Steel No. III	High-Chromium Steel, No. VI	Austenitic Alloy, No. 8
Coefficient of thermal expansion, per ° C.			
at 300° F.	11.6	10.8	16.5
500	12.6	11.3	17.3
700	13.4	11.8	17.8
900	13.8	12.0	18.0
1100	14.1	–––	18.2
Thermal conductivity, per ° C.			
at 300° F.	0.080	0.062	0.044
500	0.078	0.062	0.046
700	0.075	0.063	0.049
900	0.072	0.063	0.052
1100	0.070	0.063	0.055
1300	0.067	0.064	0.058

strength have poor impact properties in some directions of the forging "grain", especially in large pieces such as turbine disks.

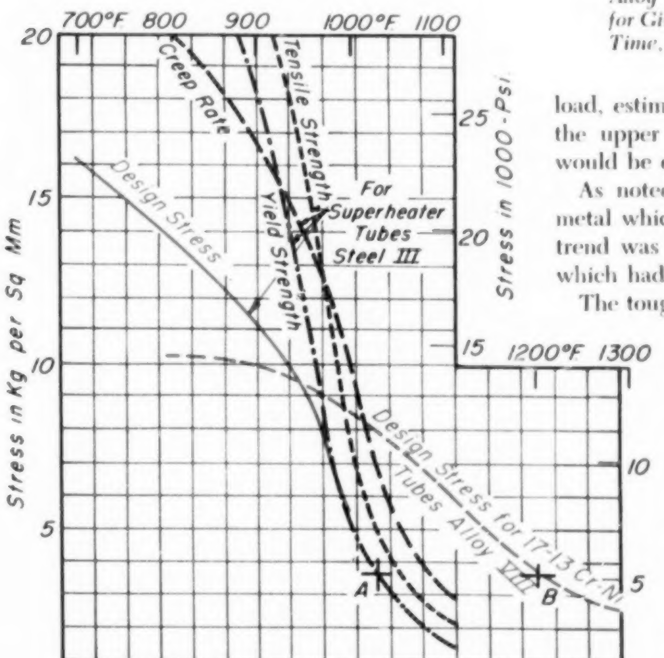
We believe that elongation and contraction in area in a long-time tensile test can be taken as an indication of the toughness at operating temperatures and long-time loading. By way of example, these values for the high Cr-Ni-Mo alloy listed as No. X in Table I are given in Fig. 3 when tested at 600° C. (1110° F.) after "warm-cold" forging to a reduction of 10%.

These tests are representative of many which were made in the preliminary investigations prior to the design of this high-temperature power station. In this particular series they ran up to 33,700 hr. and show a definite minimum in the elongation at rupture (A on the dashed curve in lower drawing) and in the contraction in area (numbers along the time-rupture curve in the upper drawing) at about 1000 hr. The load corresponding to these elongation and contraction at rupture values, 27 kg. per sq. mm., is a little less than twice the 100,000-hr. breaking load, estimated as 15 kg. per sq. mm. (Point B on the upper curve) – that is, at a stress that never would be encountered in operation.

As noted above, these tests were performed on metal which had been "warm-cold" forged, but this trend was also found in quenched austenitic alloys which had no cold work.

The toughness at room temperature (of interest in connection with repairs) was determined from impact tests at 20° C. after the steel had been annealed under no load at the operating temperatures of 600 and 650° C. for various times. Figure 4 gives results of such tests for the same alloy No. X, and shows how the impact curve approaches a value of about 8 m-kg. per sq. cm. (tested at room temperature) after having been held at 600° C. (1110° F.) for 10,000 hr. The nitrogen-free alloy No. VIII, either with or without an addition of 2% Mo, also loses impact strength at 650° C. (1200° F.) although longer holding times are necessary.

Fig. 2 – High-Temperature Properties of Cr-Mo Steel Superheater Tubes and Permissible Design Stress (in Color). For comparison, design stress versus temperature is shown dotted in color for 17-13 Cr-Ni tubing. "DVM Creep Rate" is 1010 ⁴ per cent per hour during the 25th to the 35th hour



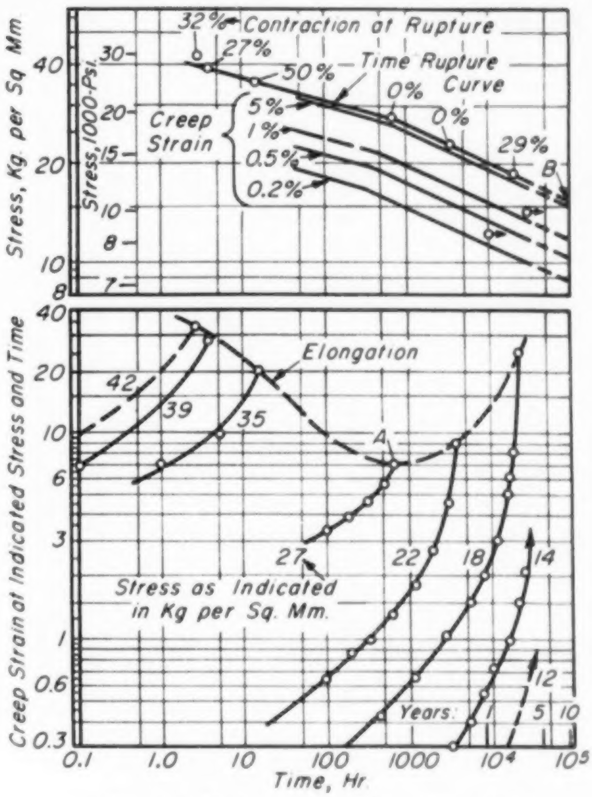


Fig. 3 – Strain Versus Time (Creep) at 600° C. (1110° F.) of 17-14-2 Cr-Ni-Mo Alloy No. X of Table I, and (Above) Stress for Given Extension (or Rupture) at Prolonged Time, Extrapolated Beyond 33,700 Hr.

Corrosion in Hot Steam

These austenitic Cr-Ni alloys, therefore, seem to be free from the service embrittlement encountered with the older low-alloy heat treated steels such as the compositions containing 0.12 C, 1.5 Ni, 0.8 Cr, and 0.8 Mo.

MICROSTRUCTURAL STABILITY

Sigma Phase – Alloys with 16% Cr and 13% Ni were so chosen that they lay as far as possible in the brittle-free austenite region. Appearance of the Fe-Cr intermetallic compound after long heating in service at 600 to 650° C. was thereby repressed. This effort to eliminate sigma phase by choosing an inherently stable austenitic alloy was influenced to a considerable extent by information gained from the experience of American steel experts.

Carbide embrittlement was prevented by stabilization with columbium. Care was taken to avoid "overstabilization", leading to the precipitation of undesirable compounds of columbium. To this end the Cb content was held to 0.2% plus ten times the percentage of carbon.

Intergranular Disintegration – Mechanical embrittlement by carbide precipitation is frequently accompanied by a loss in corrosion resistance of the steel, the austenite constituent becoming prone to attack along the grain boundaries.

In answer to the objection that very pure boiler water was to be used and that only steam was present in the superheater, our experience with similar test equipment at high temperatures indicates that grain-boundary attack proceeds faster with weak reagents than with strong ones. This is especially true for the condensate that goes into the superheater every time the boiler shuts down. In test installations mentioned we have observed many typical cases of intergranular attack in the last few years, but it never has been found in tubes of austenitic alloys stabilized with titanium or a combination of titanium and columbium.

Stress-Corrosion – We did not carry out stress-corrosion experiments. It appears that the tendency for stress-corrosion decreases with increasing stability of austenite – which we very earnestly strove for. The tube turns in the superheater were bent while cold, and although cracks were formed in such turns by immersing them in a solution of calcium chloride and mercurous chloride, we have yet to find them in the actual superheater tubes after 6400 operating hours. The laboratory test appears to be overly severe and we can find no reason to specify a relief anneal following cold bending.

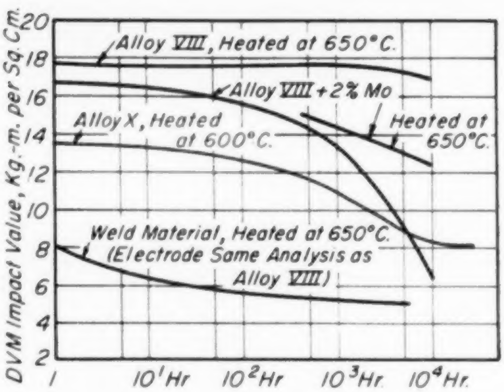


Fig. 4 – Room-Temperature Impact Tests on Austenitic Alloys VIII and X and Weld Metal After Being Heated Without Load for Extended Periods at High Temperature

EFFECT OF COMBUSTION GASES AND STEAM

As mentioned, a chromium content in excess of 5% is used to give sufficient *(Cont. on p. 180)*

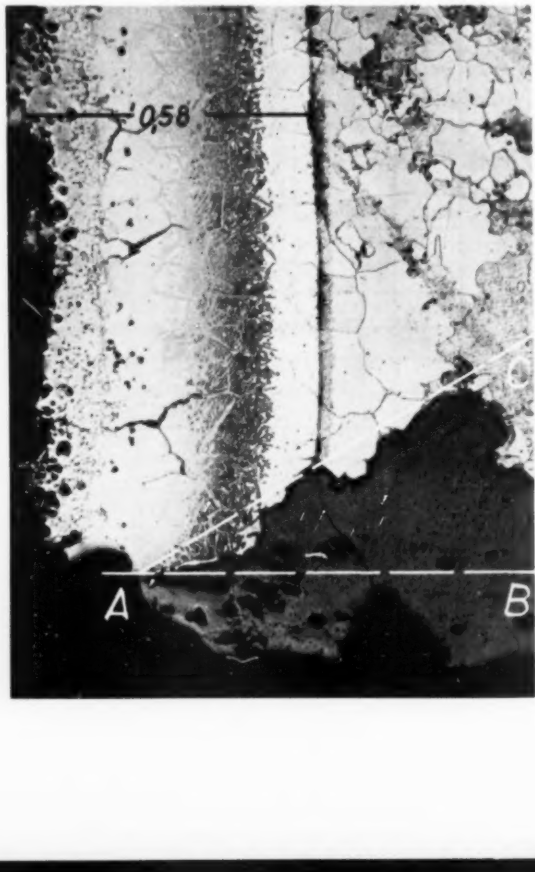


Fig. 5 – Sample of Aluminized Ferritic Steel Casting for Turbine Casing After Heating in Air for 14,470 Hr. at 600° C. (1110° F.). Diffusion zone at left is relatively unattacked. Original edge AB at botttom has oxidized back to AC. 75 ×. Analysis: 0.20 C, 0.50 Si, 0.6 Mn, 0.10 Cr, 0.5 Mo

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Overheating of Boron Steel

PITTSBURGH

In addition to the work presented by Mr. Field in his article "Effect of Boron on the Overheating of Steel" in the August 1953 issue of *Metal Progress*, studies of a similar nature have been performed at the Duquesne Works of U. S. Steel Corp.

The results of these studies on boron steels bear out the findings of Mr. Field. In one experiment commercial heats of C 10 B 50 and A.I.S.I. 14 B 27 steels treated with the 12% boron alloy showed evidence of overheating at temperatures of 2200° F. and in the 2300 to 2400° F. range, respectively. In contrast, a commercial heat of A.I.S.I. 14 B 27 treated with a special alloy addition agent showed no evidence of overheating at 2500° F. Also, the addition of ferrotitanium along with the ferroboron, and the addition of a special boron addition agent containing titanium, showed only a slight tendency toward overheating in the range of 2400 to 2500° F.

We believe it important to record, however, that in our studies the samples revealed no evidence of overheating *after* subsequent forging and heat treatment. This fact is also evident in the fracture samples and elongation values presented in Fig. 2 of Mr. Field's report (p. 80 of the August issue of *Metal Progress*). This seems to indicate that evidences of overheating that may exist in the steel at the rolling temperature *prior* to rolling will be eliminated by hot rolling.

On this basis the "lowering of the overheating temperature" by additions of ferroboron would seldom affect the final product since hot work is performed after heating to the usual hot working temperatures. From a practical viewpoint, danger would exist only in multi-stage forging where only a small amount of hot work is performed after final heating.

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Comment on Patent Disclosures (Minimum Requirements)

CLEVELAND

The short article by C. H. Gerlach in *Metal Progress* for August 1953, p. 122, erroneously refers to "reduction to practice" papers when he is actually talking about "first written description". I wish to emphasize that a good written description or "disclosure" is not a reduction to practice. The patent laws recognize only two ways of achieving a reduction to practice:

1. Filing an application in the Patent Office. This is known as a "constructive" reduction to practice. (It is excellent because its date and extent are indisputably established.)

2. Making a device embodying the invention, or practicing the method constituting the invention, and testing such device or method in the manner or in the surroundings in which it is ultimately to be used. This is the second type of reduction to practice, usually termed an "actual" reduction to practice.

Mr. Gerlach is quite correct in emphasizing the importance of a good written description, because, while we talk glibly about "first to conceive", there is no X-ray capable of showing when an inventor conceives an idea, and usually a written or oral description is the first evidence of conception. The written one is of course much more susceptible of proof. If you can achieve a reduction to practice, and can prove its occurrence by a number of reliable witnesses, you will not need a written description, although the legal profession is highly in favor of writing the description anyhow, to guard against any question as to the extent of actual reduction to practice.

T. J. Doran
Law Offices of
Hyde, Meyer, Baldwin & Doran

Correction to Data Sheet on Wrought Al Alloys

NEW KENSINGTON, PA.

We are concerned over the error that appeared in the Data Sheet on Wrought Aluminum Alloys, published in the August issue of *Metal Progress*. In the column "Characteristics and Uses", the comments on 11 S and 17 S have been transposed; those for 53 S - T 6 apply to 75 S - T 6, and those for 75 S - T 6 apply to 61 S - T 6. An error in proof reading appears in

(Continued on p. 124)

Correspondence

(Continued from p. 122)

footnote (a), in which the value ½ was omitted in the explanation of the half-hard temper.

Also, we would like to call attention to the fact that among the non heat treatable alloys, we include CD 1 S (99.6% Al), A 50 S and C 57 S which do not appear in the *Metal Progress* tabulation. The first of these is used for applications requiring relatively high-purity aluminum for resistance to corrosion; the others are new alloys which are being put to quite extensive use. We think they should have been included.

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Chief, Mechanical Testing Div.
Aluminum Research Laboratories
Aluminum Co. of America

Heat Resisting Alloys

LONDON, ENGLAND

It is in gas turbine uses that the highest demands are made on heat resisting alloys. Current practice in Britain is to use a ferritic alloy for turbine disks in most of the modern engines and new designs. Such use can only be achieved by cooling the turbine disks so that the temperature does not exceed 1100 to 1150° F., this being the maximum operating temperature for any ferritic alloy working under stressed conditions. Before this comparatively recent change to ferritic materials, the austentic alloy G 18 B was widely used for turbine disks, and is still in use on early engine designs. More recently, a 12% Cr ferritic steel with a very high creep strength has been produced by W. Jessop & Sons Ltd., Sheffield, England. Called H 46, it is used in most current engines being produced, as well as in many prototypes. Its composition is 0.15 C, 0.57 Mn, 0.4 Si, 11.5 Cr, 0.45 Mo, 0.25 Cb and 0.30% V.

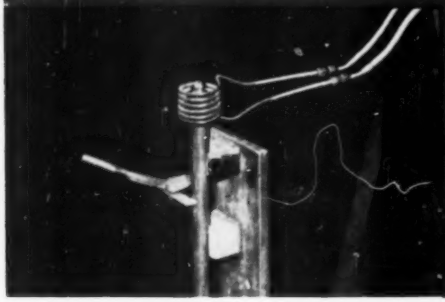
The same company has recently brought out an alloy along the lines of Discaloy. Known as G 56, it has good creep strength and a very high proof stress which is not usual in austenitic materials. This is a low-carbon, 13% Cr, 23% Ni alloy. Its high proof stress is developed by a carefully controlled heat treatment, involving no "warm working" operation. Although British designers prefer to use ferritic alloys for the disks, an alloy of the G 56 type may offer the designer some advantages over the ferritic alloys for special uses.

The heat treatment of G 56 consists of a normalize from 2010° F., followed by aging to develop optimum creep and tensile properties. Typical room-temperature properties of G 56 are as follows: 0.1% yield strength, at 94,700 psi.; ultimate tensile strength, 150,900 psi.; elongation, 26%; reduction of area, 27½%.

For turbine-blade alloys, the essential features are good creep and fatigue properties at elevated temperatures. G 32 (introduced a few years ago) fulfills these requirements, but being a cobalt-base alloy, it was considered until recently in some quarters to be strategically undesirable. This criticism no longer applies. The composition of G 32 is

(Continued on p. 126)

DIESEL ENGINE MANUFACTURER CUTS COSTS WITH *EASY-FLO*



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PART AND JOB	TIME CYCLE	TEST RESULTS
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Intake rocker arm to shaft, done same as above.	282 secs. 2 pieces	Same result as above.
Tappet plugs to tappet body, induction brazed with a ring of 3/32″ EASY-FLO wire preplaced.	72 secs. each	"Parent metal fails before brazed joint when attempting to press plug from tappet body."
Ball ends to seamless steel tubing push rods, induction brazed with a ring of EASY-FLO No. 3 1/16″ wire preplaced. (Illustrated above)	45 secs.	"Tube bulges before joint failure when attempting to push rod ends out of tubing."
Cup ends to seamless steel tubing push rods done same as above.	50 secs.	Same result as above.

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Correspondence

(Continued from p. 124)

0.3 C, 0.8 Mn, 0.3 Si, 12 Ni, 19 Cr, 45 Co, 2 Mo, 1.2 Cb, 2.8 V. It is also proving to be a suitable alloy for making extrusion dies, particularly for nonferrous materials. The precision casting variety of this alloy is known as G 34. A more recent turbine-blade alloy is G 42 which can be used at higher operating temperatures than G 32. It is particularly suitable for the temperature range 1560 to 1650° F. where it has a very high creep strength. Its basic composition is 25 Co, 19 Cr, 15% Ni, plus carbide-forming additions.

Creep and fatigue strength are less important for nozzle guide vanes than for turbine blades, since operating stresses are lower. Good resistance to oxidation is required, together with good thermal shock characteristics, and since nozzle guide vanes are often made by precision casting, good casting properties are essential. In this field G 19 (wrought or cast) is of particular interest, as also is the casting alloy G 34 previously mentioned. Typical composition of G 19 is: 0.40 C, 0.80 Mn, 1.0 Si, 13 Ni, 19 Cr, 1.8 Mo, 2.5 W, 3 Cb and 10% Co. The wrought material is normalized at 2010° F.; "as-cast" material may be put into service without any previous heat treatment unless the castings are large or intricate, when it is advisable to stress-relieve. The latest alloy for nozzle guide vanes is known as G 39. This has good casting properties and good oxidation resistance up to 2000° F., but it is perhaps more notable for its excellent resistance to cracking as caused by thermal shock. It is recommended for nozzle guide vanes.

Although the emphasis has been placed on the important field of gas turbines, there are of course many industrial demands for less expensive alloys having good heat resistance, high creep strength and oxidation resistance. The alloy G 29 has been introduced with these points in view. It is suitable for temperatures up to 1740° F., where it exhibits creep strength of a comparatively high order. It can be supplied as forgings, castings, wrought bar or sheet; it is readily weldable.

T. Bishop

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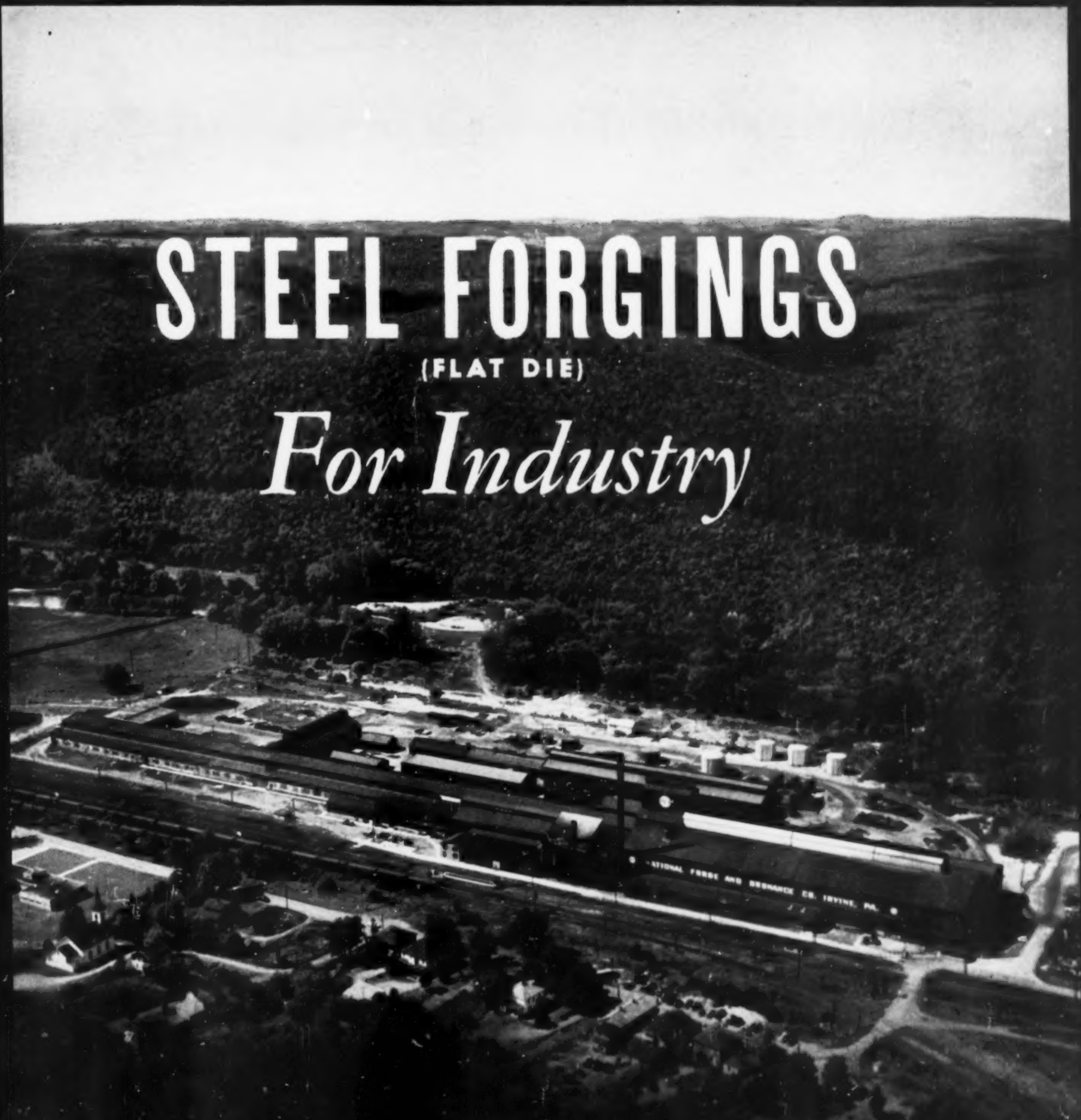

NATIONAL FORGE AND ORDNANCE

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Personal Mention

George A. Roberts

Alexander R. Troiano

George A. Roberts, national vice-president, has been elected vice-president in charge of technology of Vanadium-Alloys Steel Co., Latrobe, Pa. In his new role, he will direct the company's research and development program and head the technical staff. Dr. Roberts joined the company as laboratory technician in 1941 and in 1945 was named chief metallurgist. He attended the United States Naval Academy for two years, completing his studies at Carnegie Institute of Technology with the degrees of B.S M.Sc., and D.Sc. Author of numerous technical papers, Dr. Roberts is also co-author of the book "Tool Steels", published by the American Society for Metals in 1944. His vocational interests have covered the fields of heat treatment and physical metallurgy of steel, alloy steels and powder metallurgy. At the present time he is consultant on powder metallurgy to the Stevens Institute of Technology. Dr. Roberts has served on the Publications Committee for several years, and is a past chairman of the Pittsburgh Chapter. He is a member of various other technical societies, and is vice-chairman of A.S.A.-A.S.T.E. Committee B-52 on the standardization of materials for tools, dies, gages and fixtures, and is also a national director of the Metal Powder Association.

Alexander R. Troiano has been named head of the department of metallurgy at Case Institute of Technology, Cleveland, after having served as professor of metallurgy since 1949. He has been acting head of the department since September. Dr. Troiano received the degree of bachelor of arts from Harvard University in 1931. For the next five years he was an instructor in physics at Middlesex College, afterward returning to Harvard; in 1937 he received the master of science degree from Harvard University and Massachusetts Institute of Technology. From 1937 to 1939 he was an instructor in the Harvard Graduate School, from which he received the doctor of science degree in 1939. For the next ten years Dr. Troiano was professor and acting head of the department of metallurgy at University of Notre Dame. In 1941, he received the Robert W. Hunt Award given by the American Institute of Mining and Metallurgical Engineers, of which he is a member. He is also a member of the American Foundrymen's Society, the American Society for Testing Materials, the American Crystallographic Society, and the British Iron and Steel Institute. He is a past chairman of the Publications Committee. Dr. Troiano is actively engaged in research and consulting work for various corporations.

Gordon W. Johnson has joined the research and development staff of Alloy Engineering & Casting Co., Champaign, Ill., as associate project director on casting design-process manual. Mr. Johnson was formerly supervisor of foundry research at Armour Research Foundation, Chicago, and for twelve years previously was chief metallurgist at American Hoist and Derrick Co., St. Paul.

John L. Ham has been appointed director of the metallurgical research department of National Research Corp., Cambridge, Mass., the position formerly held by James H. Moore, who became general manager of the company's wholly owned subsidiary, Vacuum Metals Corp. Prior to joining National Research Corp. in 1952 as project manager in charge of physical metallurgy, Mr. Ham was associated with the Climax Molybdenum Co. in the research laboratories.

Lorin L. Ferrall has been appointed assistant vice-president of Crucible Steel Co. of America, Pittsburgh, and **David I. Dilworth, Jr.** moves into his former position as director of metallurgy for the same company. Previous to his new assignment, Mr. Dilworth was assistant director of metallurgy, a position he has held since January 1953, after serving as chief metallurgist of the company's consolidated Sanderson-Halcomb Works, Syracuse, N. Y.

Jack C. Sprague was recently appointed chief metallurgist in the valve division of the Eaton Mfg. Co., Battle Creek, Mich.

Heinrich K. Adenstedt has joined the Lycoming-Spencer Div. of the Avco Mfg. Corp., Stratford, Conn., as staff engineer and is in charge of materials problems on gas turbine development programs. Mr. Adenstedt will continue titanium work for the U.S. Air Force under direct contract from W.A.D.C.

Bernard J. McCarthy, who graduated from the University of Denver in June with a B.Sc. degree in mechanical engineering, is now employed by Bacon Vulcanizer Mfg. Co., Oakland, Calif., in the development section of the engineering division.

REVERE
Extruded Shape SAVES
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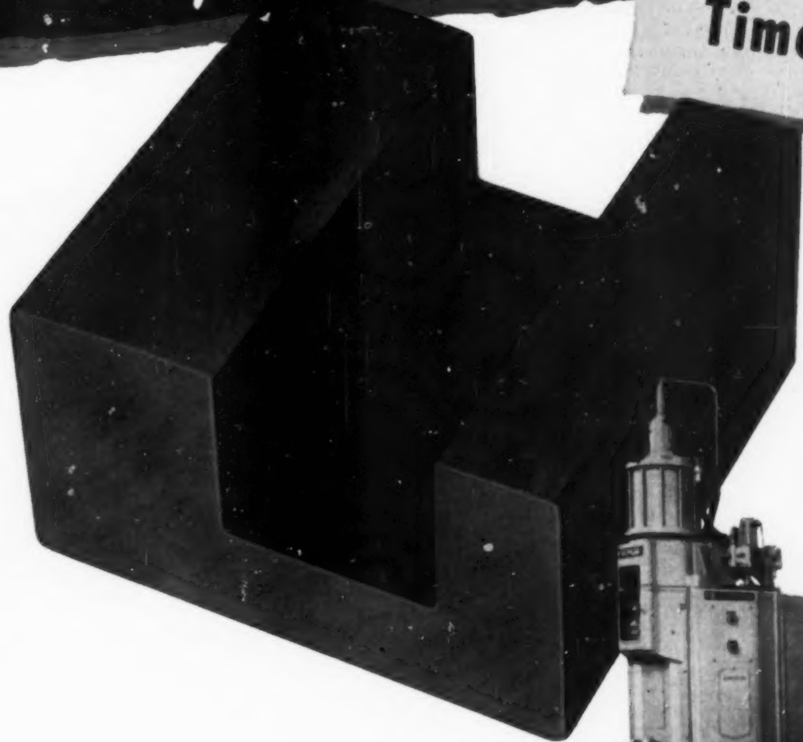

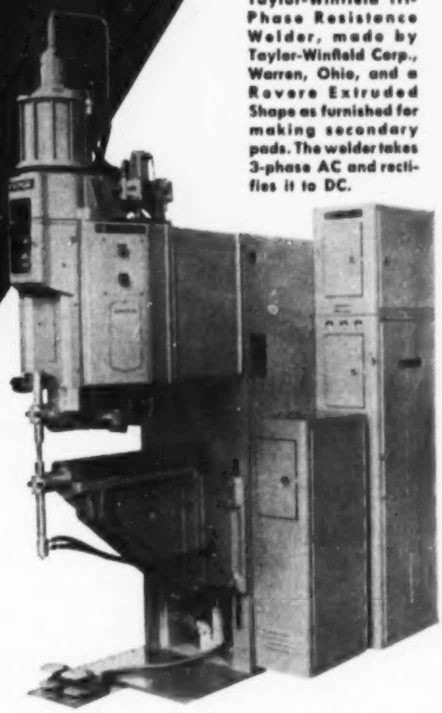

Taylor-Winfield Tri-Phase Resistance Welder, made by Taylor-Winfield Corp., Warren, Ohio, and a Revere Extruded Shape as furnished for making secondary pads. The welder takes 3-phase AC and rectifies it to DC.

● The channel shape illustrated here is a Revere Extruded Shape in copper, as supplied to the Taylor-Winfield Corp., Warren, Ohio. After a small amount of machining, it becomes a secondary pad in the Taylor-Winfield Tri-Phase Resistance Welder. Originally the pad was machined out of solid bar, 2" x 3½". The bar cost $11.73 per foot. The extruded shape substituted for the bar, being nearer the finished form, weighs less and costs $10.03 per foot, an immediate saving of $1.70. You can see right there that though the shape costs a bit more per pound, it still saves money. But that is not all. Taylor-Winfield says that the shape has cut machining time by 50%. As every manufacturer knows, machining is expensive, and cutting it in half saves a lot of cash. In addition, there is less scrap, and production rolls along faster. We have in our files a Call Report stating: "Customer has found the extruded section very satisfactory, and bases his machining time-saving on production runs and not estimates."

Credit for this fine achievement has to be shared by a number of people, both in Taylor-Winfield and in Revere. Our Sales and Technical Advisory staffs collaborated closely with the customer's engineering, production and purchasing personnel. Everybody considered all angles, and worked out this money-saving plan.

So we suggest that if you are doing any extensive machining of copper and copper alloys, or aluminum alloys, it would be a good idea to look into Revere Extruded Shapes. They might offer you important economies. We will be glad to consult with you. Just get in touch with the nearest Revere Sales Office.

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Personals

John C. Hamaker, Jr. has joined Vanadium-Alloys Steel Co., Latrobe, Pa., as research metallurgist. Prior to this assignment, Dr. Hamaker was plant metallurgist for the General Iron Works Co., division of Stearns-Rogers Mfg. Co. at Denver.

Harry F. Ross is now metallurgist and supervisor of the heat treating department at National Acme Co., Cleveland.

Paul E. Nelson has resigned from the Hotpoint Co., Milwaukee, to become supervisor of nondestructive testing at the Solar Aircraft Co., Des Moines, Iowa.

John W. Shoop has joined the Elgin Sweeper Co., Elgin, Ill., as factory manager. Mr. Shoop was formerly production and process engineer with the central manufacturing department of the American Radiator & Standard Sanitary Corp., Louisville, Ky.

Elwood R. Rinehart, former supervisory materials engineer of the Materials and Process Control Div., U.S. Naval Air Station, Seattle, Wash., has accepted a position as general supervisor of the chemical and metallurgical processes, Chance Vought Div., United Aircraft Corp., Dallas, Texas.

S. Eric McFall has transferred from the technical department of the Aluminum Co. of Canada, Montreal, to become manager of the metallurgical section of the welding division of Aluminium Laboratories Limited, Kingston, Ont.

Earl L. Kunz, formerly with the Ladish Co., Cudahy, Wis., as metallurgical engineer, now holds the same position with Rohr Aircraft Corp., Chula Vista, Calif.

Walter E. Littman, graduate of the Massachusetts Institute of Technology, has accepted a position in the metallurgy department of the Timken Roller Bearing Co., Canton, Ohio.

Henry A. Domian is now a 1st lieutenant in the U.S. Air Force and is stationed at the University of Michigan as a graduate student in metallurgical engineering. Lt. Domian completed his undergraduate training at Syracuse University in 1951.

Alfred J. Mosley, formerly with the Jeffrey Mfg. Co. of Columbus, Ohio, is now associated with the engineering staff of Gilfillan Bros., Inc., Los Angeles.

Charles W. Andrews has resigned as laboratory supervisor at Thompson Products, Inc., Tapco Plant in Euclid, Ohio, to join the engineering department of Jones & Lamson Machine Co., Springfield, Vt., as metallurgist.

George W. Yearley has been named director of research and development for the True Temper Corp., Cleveland. Mr. Yearley joined the American Fork & Hoe Co., Geneva, Ohio, in 1929 as metallurgist and in 1946 was made manager of the Geneva Works, a position he held until his new appointment.

Robert Misshula was recently named vice-president of the Alfred Heller Heat Treating Co., Inc., New York City.

Personals

Dwayne L. Day ⊕, previously associated with Battelle Memorial Institute, Columbus, Ohio, for over six years, is now a metallurgical engineer in alloy development for Titanium Metals Corp., Henderson, Nev.

John J. Lawless, Jr. ⊕ is now associated with Metallurgical Consultants, Inc., Los Angeles, a firm newly organized to provide staff metallurgical service for western industry.

William N. Dunlap, Jr. ⊕ is presently employed by the Friez Instrument Division of Bendix Aviation Corp., Baltimore, as an assistant project engineer.

Anderson W. Pollard ⊕ has been appointed sales representative of the Worcester Pressed Steel Co., Worcester, Mass., for the Buffalo and Pittsburgh areas, making his headquarters at Rochester, N.Y. Mr. Pollard was formerly vice-president of Ex-R-Reamer and Tool Corp., Rochester, N.Y.

Robert Denison ⊕ has joined the staff of Armour Research Foundation, Chicago, as a research metallurgist after having been with the Sheffield Steel Corp., Houston, Tex., for the past nine years.

James Litman ⊕, formerly with Wico Electric Co., West Springfield, Mass., in the industrial engineering department, is now in the research and development division of Lear, Inc., Los Angeles.

H. Neville Mason ⊕, for many years associated with Dominion Bridge Co. Ltd., Montreal, is now president of the newly organized Industrial and Mining Supplies, Ltd., Montreal.

J. William Wigert ⊕ is now employed as supervising engineer of the development engineering section of the lighting division of Westinghouse Electric Corp., Cleveland.

Quentin E. Charlesworth ⊕ is associated with the Bristol Steel & Iron Works, Inc., Bristol, Va., after 31 years with Bethlehem Steel Co., Bethlehem, Pa., where he started work as an apprentice template maker and for the past eight years has served as superintendent of fabricating shops.

Arthur G. Metcalfe ⊕, a British powder metallurgist with several years' production experience, has been appointed to the metals research department staff at Armour Research Foundation of Illinois Institute of Technology, Chicago, as full research metallurgist. Dr. Metcalfe holds B.S., M.S., and Ph.D. degrees from Cambridge University, England, and prior to his present assignment was employed as metallurgist with the Deloro Smelting and Refining Co., Deloro, Ont.

George C. Priester ⊕ has retired from active duty at the University of Minnesota after teaching in the department of mathematics and mechanics for 43 years, being head of the department for 12 years. Dr. Priester was recently awarded a citation as distinguished alumnus of the University of Michigan for his work in education and research.

K. Piekarski ⊕, formerly metallurgical instructor at Ryerson Institute of Technology, Toronto, is now a metallurgical engineer with Houdaille-Hershey of Canada, Ltd., Oshawa, Ont.

NEW PROTECTIVE COATING CHEMICAL FOR ALUMINUM

ALODIZING

Alodizing with "Alodine,"* a new technique in the protective coating of aluminum, was made available for production-scale use in 1946. Since that time Alodizing has largely supplanted the more elaborate, costly and time-consuming anodic treatments in the aircraft and other industries.

Continuous and successful industrial use has clearly demonstrated the simplicity and economy of the Alodizing process as well as the effectiveness of the "Alodine" amorphous coatings, particularly as a base for paint. In fact, the paint-bond that Alodized aluminum provides has been found to be superior to that possible with chromic acid anodizing.

The corrosion-resistance of unpainted aluminum Alodized with "Alodine" Nos. 100 or 300 is excellent, easily meeting the requirements of Specification MIL-C-5541. However, a need for protection of unpainted aluminum, even better than that obtained with chromic acid anodizing, has long been recognized.

NEW IMPROVED "ALODINE" DEVELOPED By ACP RESEARCH CHEMISTS

Several years of intensive research have now led to a new type of "Alodine," designated as "Alodine" No. 1200. This new protective coating chemical forms an amorphous mixed metallic oxide coating of low dielectric resistance that provides unusually high corrosion-resistance for unpainted aluminum. In addition, it forms an excellent paint bond that approaches closely the high quality obtained with the earlier types of "Alodine."

After having been tested for conformance with Specification MIL-C-5541, "Alodine" No. 1200 is now about to go into production.

PROCESS DETAILS

"Alodine" No. 1200 is the only essential chemical needed to prepare the coating bath and the final rinse bath. One of its unique features is that it can be used in tanks in an immersion process, or, in a multi-stage power washer in a spray process, or, with a slight adjustment of pH, with brush or portable spray equipment in a manual process. This means that even where the simple production equipment is not available, or where touching up of damaged coatings previously Alodized or anodized is required, excellent protection and paint bonding can still be obtained with practically no equipment.

"Alodine" Trade Mark Reg. U. S. Pat. Off.

All three methods of application easily meet the requirements of Specification MIL-C-5541.

Process sequence for all three methods of application is the same as for other standard grades of "Alodine" such as Nos. 100, 300, and 600, viz.: 1. Pre-cleaning. 2. Rinsing. 3. Alodizing. 4. Rinsing. 5. Acidulated rinsing. 6. Drying.

Coating time in an immersion process ranges from 2 to 8 minutes and in a mechanized spray process is about 30 seconds. "Alodine" No. 1200 baths are operated at room temperatures (70° to 100°F.) and heating is required only if the bath has gotten cold after a "down" period.

RECOMMENDED USES FOR "ALODINE" No. 1200

"Alodine" No. 1200 is specifically recommended for coating wrought products that are not to be painted or are to be only partially painted; and for coating casting and forging alloys whether or not these are to be painted. "Alodine" Nos. 100 and 300 are still recommended for coating wrought products such as venetian blind slats, awnings, etc., that are invariably painted.

RESULTS OF TENSILE TESTS

This new "Alodine" not only retards visible corrosion and pitting, but as shown in the table below, the loss of ductility with "Alodine" No. 1200, both brush and dip after 1000 hours salt spray was less than for chromic acid anodizing after 250 hours, and for "Alodine" No. 100 and a conventional chromate treatment after 168 hours exposure.

PROCESS	SALT SPRAY EXPOSURE	COMPLIANCE WITH TENSILE REQUIREMENTS OF MIL-C-5541
CHROMIC ACID ANODIZING	168 hrs. 250 hrs. 500 hrs. 1000 hrs.	passes passes fails fails
BRUSH "ALODINE" No. 1200	168 hrs. 250 hrs. 500 hrs. 1000 hrs.	passes passes passes passes
DIP "ALODINE" No. 1200	168 hrs. 250 hrs. 500 hrs. 1000 hrs.	passes passes passes passes
DIP "ALODINE" No. 100	168 hrs. 250 hrs. 500 hrs. 1000 hrs.	passes fails fails fails
CONVENTIONAL CHROMATE TREATMENT	168 hrs. 250 hrs. 500 hrs. 1000 hrs.	passes fails fails fails

CHEMICALS ACP PROCESSES

AMERICAN CHEMICAL PAINT COMPANY

General Offices: Ambler, Penna.

Detroit, Michigan *Niles, California* *Windsor, Ontario*

Personals

Joseph Mason ⊕ was recently made head of the department of engineering mechanics of Pennsylvania State College, State College, Pa.

Vincent V. Toth ⊕ has resigned his position with the Caterpillar Tractor Co., Peoria, Ill., and is now a melting metallurgist with the Central Foundry Division of General Motors Corp. located in the Danville, Ill., plant.

George A. Medley ⊕ is now employed as mechanical engineer at Columbia Electric Mfg. Co., Spokane, Wash.

Robert B. Walder ⊕ has been elected president of the Laboratory Corp. of America, Detroit.

J. P. McCulloch ⊕, formerly foundry superintendent with Vulcan Iron and Engineering, Ltd., of Winnipeg, Man., is now metallurgist with the Canadian Sumner Iron Works, Ltd., of Vancouver, B.C.

E. A. Fox ⊕, formerly manager of the metallurgical development section, materials division, Westinghouse Electric Corp., East Pittsburgh, has been transferred to South Philadelphia where he holds the post of manager of the metallurgical development section of the steam division of the corporation.

John T. McCormack ⊕, since resigning from the metallurgical staff of Purdue University, is now metallurgical consultant with the Reynolds Metals Co. in the new research and development laboratory in Richmond, Va.

Don C. Root ⊕ has resigned from Bohn Aluminum & Brass Corp., Detroit, and is now employed as senior research engineer for North American Aviation, Inc., Los Angeles.

Robert L. Nichols ⊕, formerly a field metallurgist for the Timken Roller Bearing Co., Canton, Ohio, has joined the Earle M. Jorgensen Co., Oakland, Calif., as sales metallurgist for the San Francisco Bay area.

David L. Douglass ⊕, a '53 graduate of Pennsylvania State College with a B.S. in metallurgy, is now employed by E. I. du Pont de Nemours & Co. at its Savannah River (S.C.) project in the research laboratories.

Charles Mangiaracina ⊕ has accepted a position as mechanical engineer with the Radio Corp. of America, RCA Victor Div., Camden, N.J.

M. E. Hansell ⊕, formerly superintendent of buildings and grounds at Rose Polytechnic Institute, is now in the plating department at Allis-Chalmers Mfg. Co., Terre Haute, Ind.

Morse Hill ⊕ has joined the staff of Brush Laboratories Co., division of Clevite Corp., Cleveland, as project engineer.

William F. Watson, Jr. ⊕, formerly plant superintendent of the J. I. Case Co.'s Bettendorf, Iowa, works, has been made plant superintendent of the Rochester, N.Y. works of the A. O. Smith Corp.

R. D. Cromwell ⊕ is now employed as senior proof engineer at the U.S. Naval Purchasing Office, London, England.

Thomas F. Leibinger ⊕, who graduated from Lehigh University in June 1953, has accepted a position with Bethlehem Steel Co., Bethlehem, Pa.

Hilton N. Rahn ⊕, who received a master's degree in metallurgical engineering from Purdue University in August, 1953, is now working for Bethlehem Steel Co., Sparrows Point, Md.

Advanced Practices In Italy

(Continued from p. 88)

4. Shake-Out Area – Through repeated experiments the shake-out has been rendered entirely automatic, thus eliminating workmen from this area in which, even when positive suction was provided, the working conditions were always unfavorable due to the heat and fume from the still-hot castings soon after removal from the sand.

The equipment consists of an electro-pneumatically controlled pusher, (8) in Fig. 5, synchronized with the speed of the pan conveyer as the molds arrive. The whole flask is pushed onto the vibrating grid shake-out (9) which frees the castings and the flasks.

The castings fall into large boxes in the basement. The molding sand, through an underground conveyer, is sent to the central remixing plant. The empty flasks are transferred to an automatic opening device, (10) in Fig. 5, and the two halves are automatically placed on hooks on an overhead conveyer (2) and returned to the molding line at a speed synchronized with that of the main conveyer.

This line handles moderately sized castings capable of being molded in flasks whose cope and drag are of equal size, namely 4 in. high by 12½ in. square. Production of the eight molding machines depends upon whether the molds need cores:

	Cored Molds	Uncored Molds
Molders	8	8
Core setters	4	
Molds per hr.	550	550
Molds per man-hr.	46	69

It is hoped that this account, necessarily brief, will have given the reader the idea that in postwar Italy there is now a manufacturing organization which embraces a wide variety of operations and produces – by methods which rival the best – a diverse line of motor-driven equipment, and at the same time is an important producer of semifabricated parts.

Quality Control in the Production of Wrought Aluminum Alloys*

Aluminum alloy ingots for subsequent fabrication must be produced under more exacting conditions than are considered necessary in a sand, permanent mold or die cast foundry, necessary because the material must also be capable of being structurally deformed without failure. The problem is one of proper furnace selection, close control of a carefully chosen composition, a melting practice which provides metal of clean and uniform quality, and the development of equipment which in production will repeatedly reproduce a set of carefully worked out pouring conditions.

Metal cleanliness, one of the important factors to be considered, can be controlled only in the liquid state, so melting methods must be developed which assure the elimination of oxide inclusions and gas that may be present in the charge or introduced during melting and pouring. Further complicating the problem of making sound ingots is the fact that wrought alloy compositions are selected not for their casting qualities but for their working and mechanical properties,

(Continued on p. 138)

*Digest of "The Control of Quality in the Melting and Casting of Aluminum Alloys for Working", by R. T. Staples and H. J. Hurst, *Journal* of the Institute of Metals, Vol. 20, March 1953, p. 377-391.

Quality Control in the Production of Wrought Aluminum Alloys

(Continued from p. 136)

hence their feeding characteristics may not be the optimum. While it is true that better feeding is obtained in the more complex systems because of the presence of more eutectics, these alloys are more prone to segregation and the formation of coarse intermetallic constituents which impair workability and final properties.

The choice of a furnace is influenced by a number of considerations, the type of charge being melted, capacity requirements, the economics of using a particular fuel, and the final influence on quality. While induction melting may show lower melt loss than reverberatory furnaces, metal quality is not necessarily improved, for the continual stirring action of metal in the loops of the low-frequency furnace prevents the separation of oxide impurities. Production of high quality metal in such furnaces, therefore, requires that they be provided with an auxiliary electric-resistance holding bath. For the production of large ingots for fabrication, preference today is for duplex reverberatory furnaces which provide melting rates up to two tons per hour with hearth capacities of 10 to 15 tons. The advantage of such units is that alloying can be done in one furnace at temperatures necessarily higher than required for pouring, then the metal can be transferred and refined by holding at a lower temperature. Also a new charge may be prepared in the melting unit during the time of pouring.

It is during the undisturbed holding period that the oxides settle or float out, depending on their specific gravity. Surface fluxing frees them from entrained metal, after which the dross is skimmed off. A metal of low gas content can be produced using electric power or fuels such as coal, oil or gas, if in the melting cycle there is provided a 1 to 1½-hr. holding period at low temperatures to allow metal-gas equilibrium to be reached. The direct-chill casting process is a further aid, for a near-horizontal freezing zone in open molds favors free escape of gas at the

(Continued on p. 140)

Quality Control in the Production of Wrought Aluminum Alloys

(Continued from p. 138)

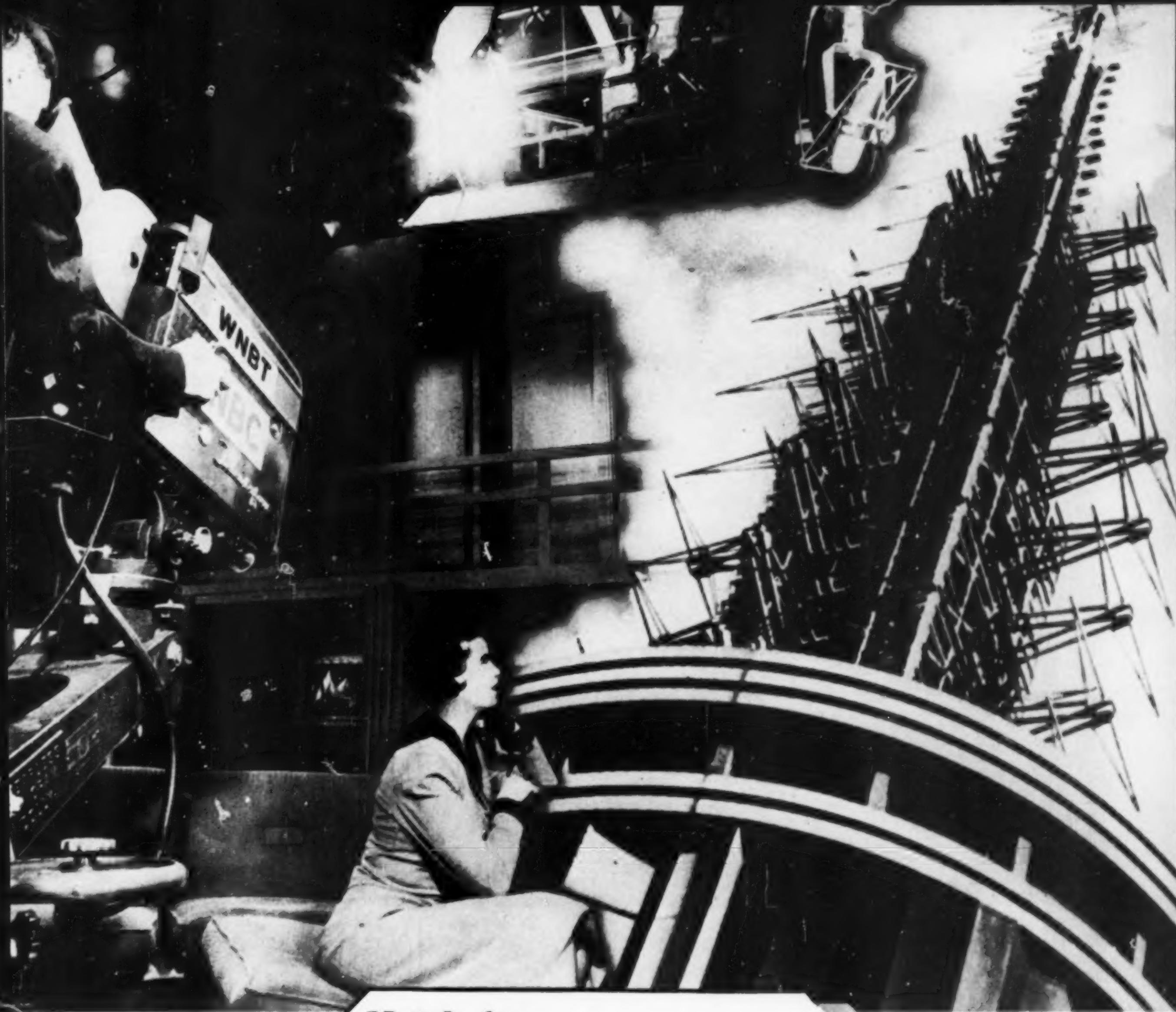
low solubility freezing temperature of the metal. Degassing is considered unnecessary; in fact, the operation generally produces turbulence, forming more oxide particles.

With the exception of magnesium, all the other principal alloying elements (silicon, copper, manganese, nickel, iron, zinc, chromium) are added pre-alloyed with aluminum. These are prepared as binary or ternary compositions in separate furnaces at temperatures of about 1380° F., with the metal being carefully protected by surface fluxes to prevent high-temperature oxidation. The source of manganese metal must be carefully selected because manganese carbide formed during thermal reduction may be carried through as hard insoluble particles to the final alloy and later present difficulties on drawing. Magnesium as an alloying element offers a wide range of alloys with attractive mechanical and corrosion resistant properties. The commercial ingot may be a source of gas and, due to the tendency of the metal to oxidize, presents a melting problem; however, this can largely be overcome by maintaining a layer of liquid cover flux on the surface of the metal bath.

Addition of 0.001% beryllium to the melt is also effective in preventing oxidation and the formation of magnesium nitride which forms during casting and results in irregular surfaces which must be completely removed before rolling. This addition of beryllium also appears to improve the hot workability of the alloys. Experience has shown that alloy melts containing a high percentage of scrap and secondary ingot give more consistent casting and working characteristics than when virgin metal and hardeners only are used. It is also recommended that a grain refiner be used to improve casting and working of not only pure aluminum but also most alloys. A particularly suitable one is a proprietary material containing boron and titanium salts with hexachlorethane.

The care exercised in preparing a

(Continued on p. 142)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Quality Control in the Production of Wrought Aluminum Alloys

(Continued from p. 140)

melt must be continued with equal regard for the methods of metal transfer and casting. Methods may differ depending on the rate of production but the aim of good metal transfer is to avoid any turbulence which will break the protective oxide film on the metal stream. Then the development of a pouring system must provide a means of closely controlling the freezing rate by maintaining a narrow range of metal and cooling water temperatures, and with a constant casting speed and metal level in the mold. When such a set of conditions has been developed and produces a sound structure, free from shrinkage, gas and segregation, this standard practice procedure must then be meticulously followed in production runs.

The various control methods outlined in the paper have made it possible in the authors' plant to successfully deliver 90% or more of the production weight cast in the form of satisfactory ingots for fabrication in rolling and extrusion mills.

G. M. Young

Cathodic Protection of Ferrous Metals*

The essentially electrochemical nature of the corrosion of a metal in an electrolyte suggests two possible methods of countering such corrosion. For example, the corrosion of iron or steel pipes buried in soil or on the sea bed, or of tanking installations, results from the establishment of an electrical circuit in which current passes due to the existence of differences in potential between metal and environment, and between anodic and cathodic areas on the metal itself. Once a circuit is established, corrosion results from anodic dissolution of the steel, the anodic areas sometimes constituting the whole area of the steel. In other instances the anodes are localized, and

*Digest of "Cathodic Protection Against the Corrosion of Iron and Steel", by Heinrich Klas, *Stahl und Eisen*, Vol. 73, July 16, 1953, p. 971.

it is with these that corrosion is localized and severe.

Protection against corrosion can be attempted in two ways, each of which is, in effect, the application of a counter-potential to oppose anodic currents. One method is to introduce into the "corrosion circuit" a base metal which is anodic with respect to the steel. The second method is to introduce into the circuit an externally generated current, opposing the natural corrosion current. In either method the article to be protected is rendered cathodic with respect to its environment.

Exact measurements can be made of the distribution of local potentials, and hence of currents, by judicious use of probe electrodes and a standard cell (such as a copper-copper sulphate half-cell), and by taking into account the electrical resistance of the environment as well as any stray currents that might be present. It is urged, however, that the results of such measurements be computed with caution, since many factors can apply which affect each environment, and conditions may vary after installation of a protective system.

Zinc, magnesium and aluminum are the only three metals which can be used in practice as protecting anodes. Of these, zinc is the weakest, and to be effective must be very pure (containing less than 0.01% each of cadmium and lead). Magnesium is used in a 6% Al, 3% Zn alloy, and aluminum is used as an aluminum-magnesium alloy. It is possible to inhibit the insulating effect of the ozide film of the latter by suitably shrouding the aluminum anode. Owing to the strongly localized nature of the anode areas, at which corrosion would occur, it is necessary to prevent the protecting current from becoming unsuitably localized. Spreading of the protective current can be accomplished by packing the anode with some highly conducting material.

If cathodic protection is to be applied by way of an externally generated current, a battery or a welding-type transformer is connected to the buried anode. The anode, which may be subdivided into many separate units distributed along the length of the article to be protected, can consist of steel or graphite bars located in coke-filled troughs. It is stated that the counterpotential

(Continued on p. 144)

Cathodic Protection of Ferrous Metals

(Continued from p. 142)

needed to protect iron in various electrolytes does not vary widely; on the average, it is approximately —0.283 v. as measured against the copper-copper sulphate standard cell, which itself is 0.54 v. nobler than steel. The required counterpotential is, therefore, —0.82 v. or —0.85 v. after allowing a small safety factor. From the known surface area of the steel body and the estimated electrical resistance of its environment, the required current to be supplied through the protecting anodes can be calculated.

In applying cathodic protection, careful attention must be paid to all operative factors, which, unless considered, may completely offset the protective measures, or cause electrochemical damage to nearby equipment. Among such factors are the following: Locally formed protective coatings may increase the effective resistance of the system, or failure of previously formed protective coatings may necessitate an increased protecting current; changes in environmental resistance; changes in potential of cast iron with time, due to corrosion of surface and production of free graphite; stray currents either acting on the given system, or originating from the protective system and causing damage elsewhere.

The costs of installing equipment for cathodic protection are clearly considerable, and the ultimate return for such expenditure is difficult to assess. The cost of corrosion has to be measured in terms of unreliability of equipment and the inconvenience of periods of shut-down resulting from corrosion failures. It is, however, a firm pointer to the value of the method, when applied under strict and competent technical supervision, that increasing use is being made of cathodic protection. A rising volume of literature on the subject reveals relatively little German interest, which is deplored since the German corrosion experts Bauer and Vogel had published the electrochemical fundamentals of the phenomena as early as 1918, and practical use had been made of cathodic protection of a German telegraph cable in 1880. C. B. LANDER

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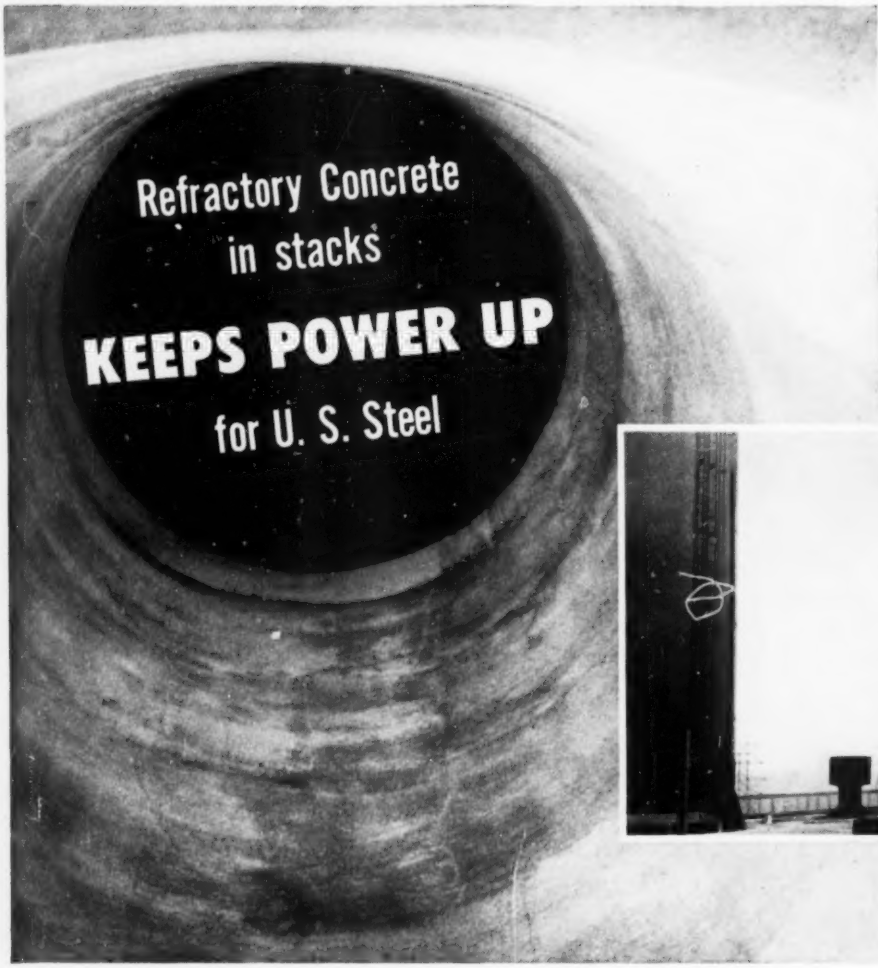

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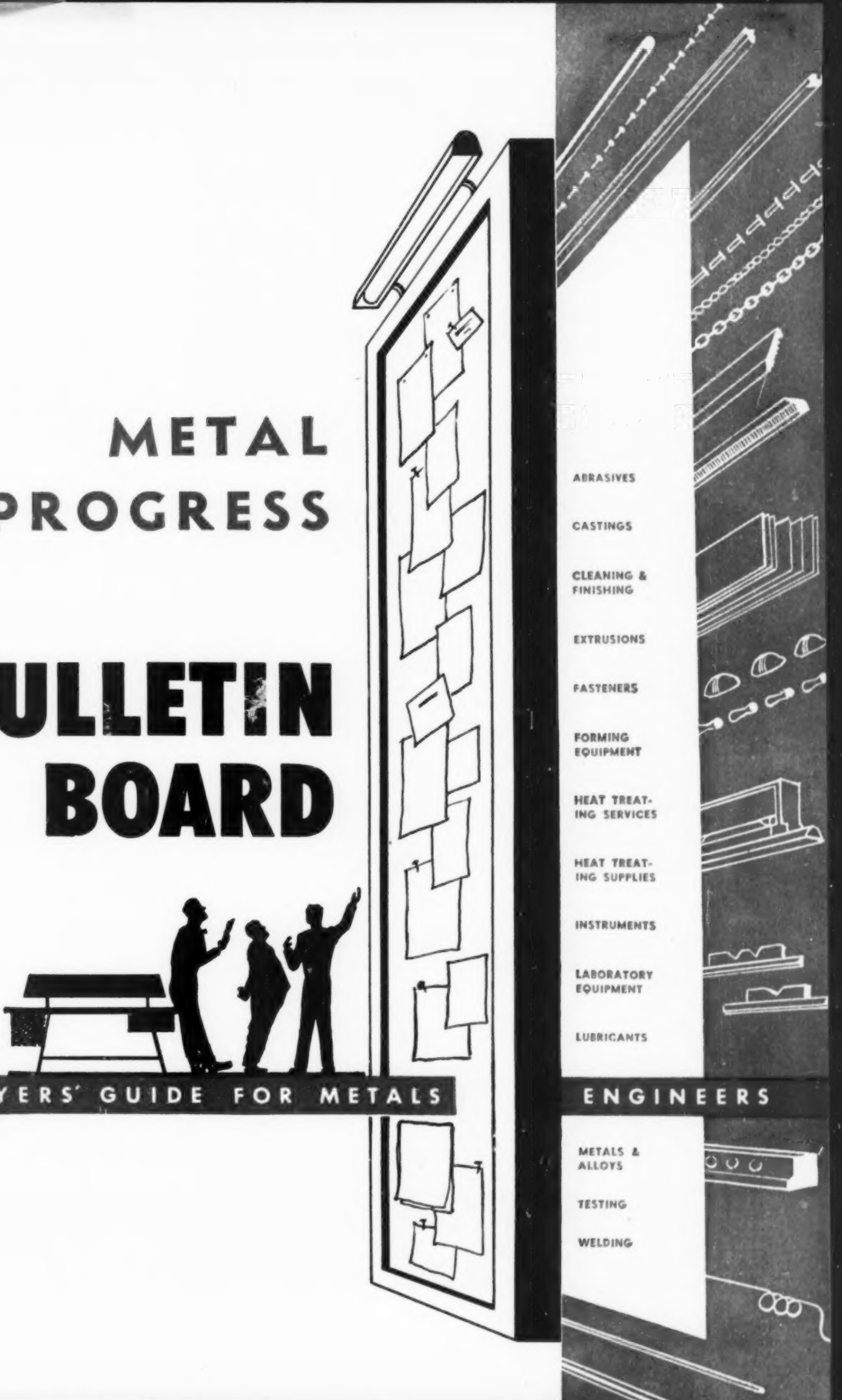

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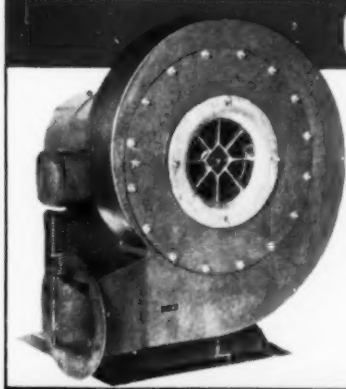

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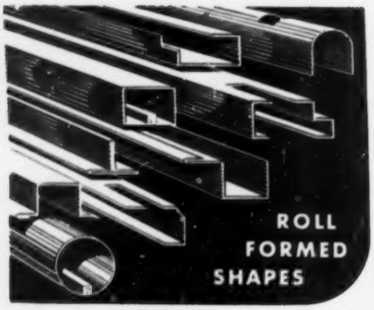

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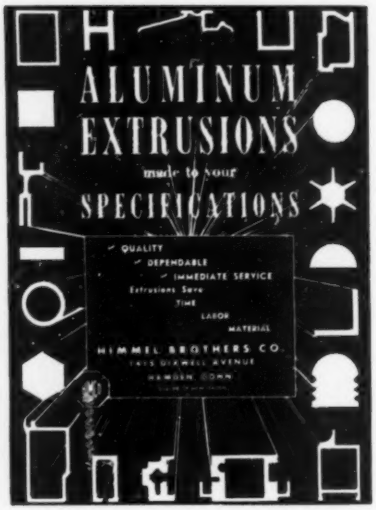

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How to measure residual stresses . . . The state of stresses produced in metals by various processes . . . Relief and redistribution of residual stresses in metals . . . How residual stresses originate, their nature and their effect on metals.

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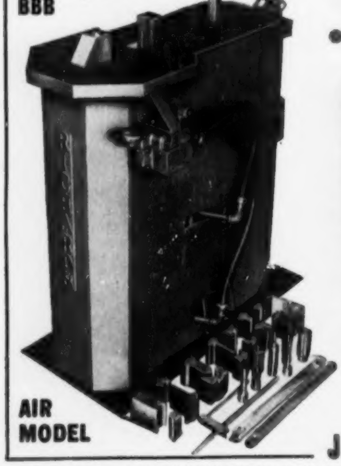

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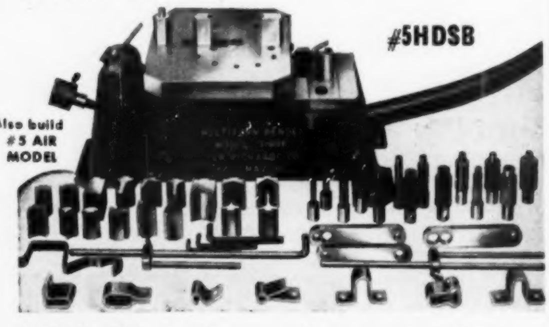

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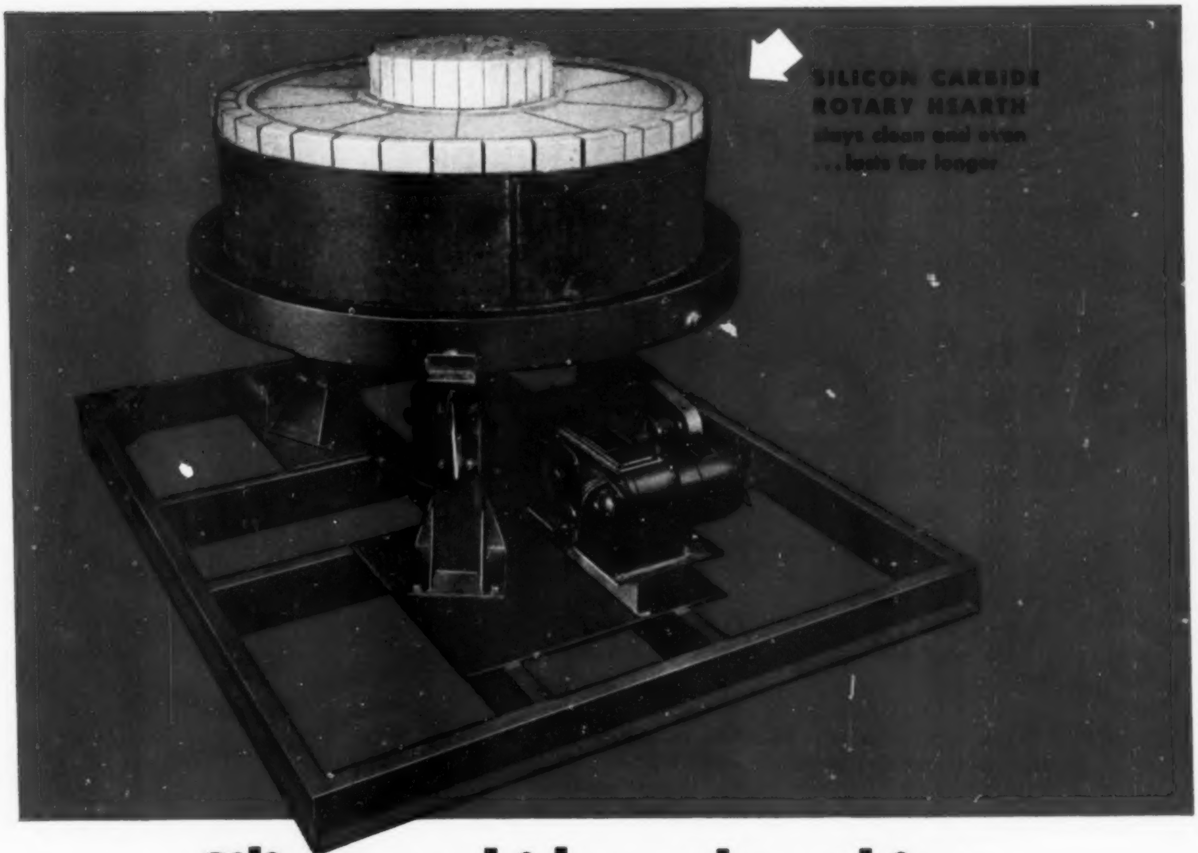
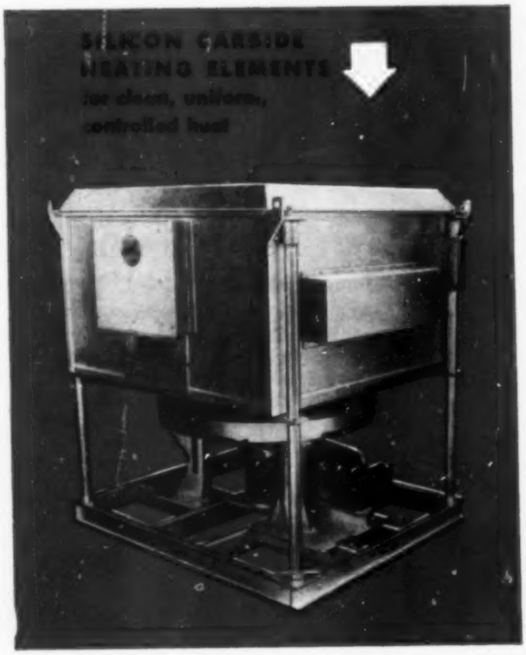


Silicon carbide makes this a better furnace . . . *two ways*



AN INTERESTING FEATURE of this W. S. Rockwell controlled atmosphere furnace is that both the heating elements and rotary hearth are made of silicon carbide.

The elements provide clean, uniform, *controlled* heat. Example: an automotive manufacturer using several of these furnaces, heats steel slugs for forging at 2200 F — and regularly turns out 500 lbs per hr per furnace.

The silicon carbide hearth provides an even work surface *that wears, and wears, and wears.* It stays clean, requires far less maintenance, and the work is easier to handle. Both the heating elements and hearth are products by

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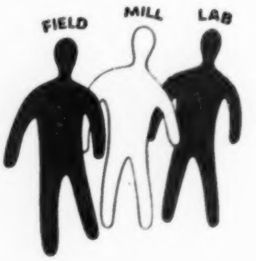

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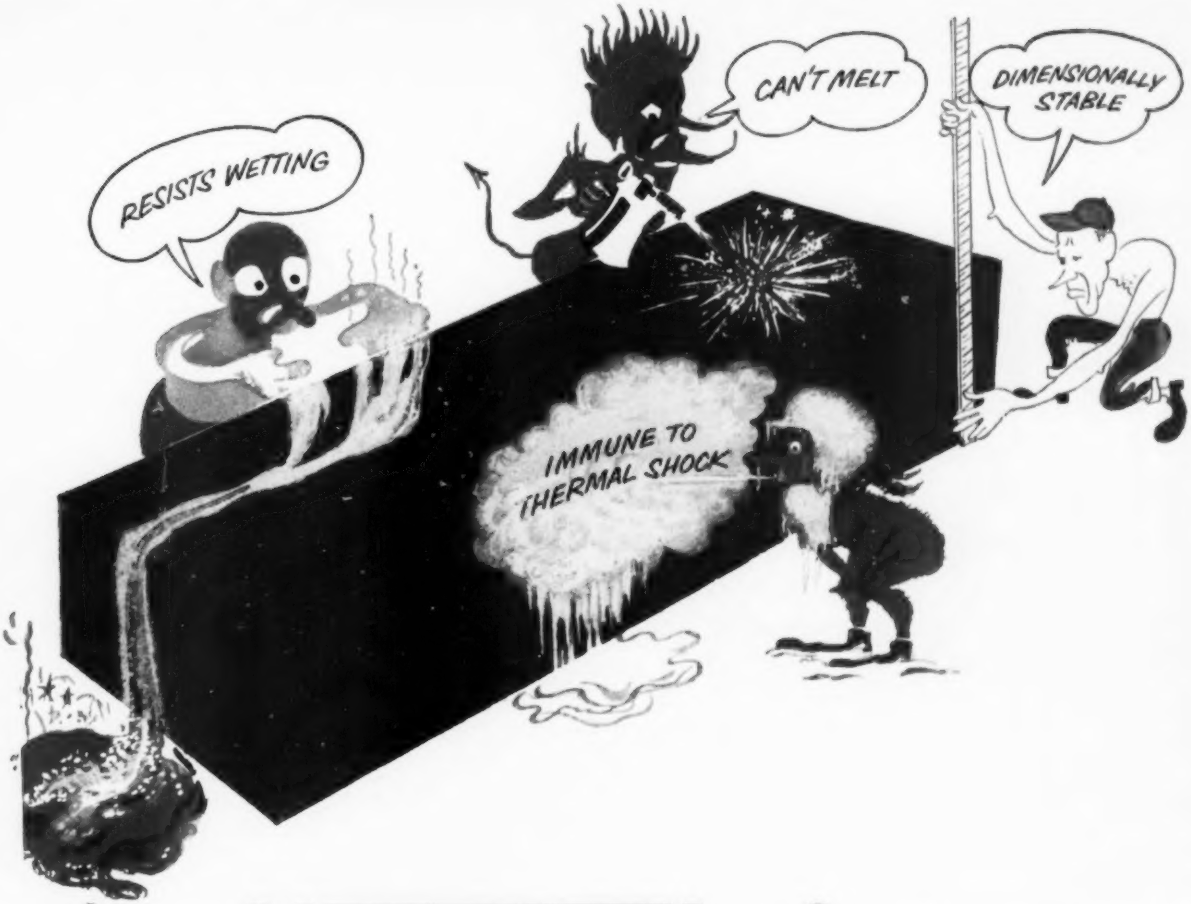
combines the extensive experience and co-ordinated abilities of Republic's *Field, Mill* and *Laboratory* Metallurgists with the knowledge and skills of your own engineers. It has helped guide users of Alloy Steels in countless industries to the correct steel and its most efficient usage, IT CAN DO THE SAME FOR YOU.



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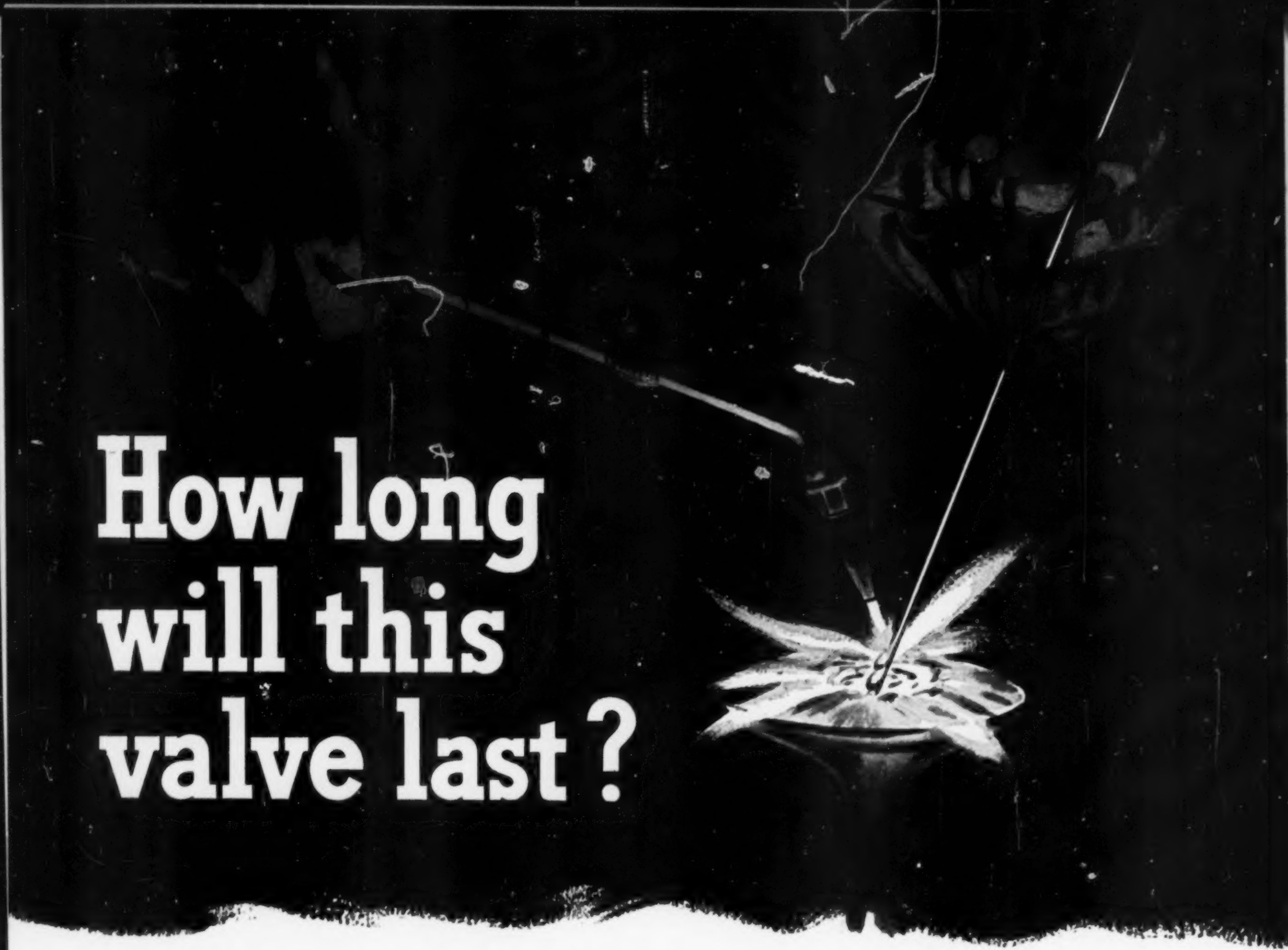
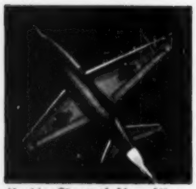
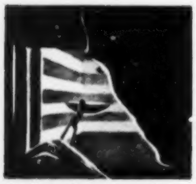
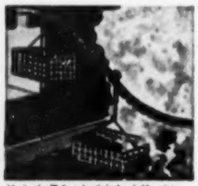




Hoskins Chromel-Alumel thermocouple alloys accurately register exhaust temperatures of jet aircraft engines.



Heating elements made of Hoskins Chromel give long life service in industrial electric furnaces, home appliances.



Hot stuff for hot jobs! Hoskins Alloy 502 is widely used by industry for many heat resistant mechanical applications.

You're looking in on a life-saving operation . . . one that's being performed on an engine valve. Not an ordinary valve for an ordinary engine. But a valve destined for long, hard service in an aircraft, tank, or heavy-duty truck engine. A valve that must be made to stand up under extremely severe operating conditions . . . high temperatures, for long periods of time, plus the destructive corrosive action of hot exhaust gases.

And what's responsible for long valve life under such gruelling conditions? Nothing less than Hoskins Alloy 717 . . . a closely controlled nickel-chromium composition developed especially for just such tough and vital service. It's highly resistant to heat . . . immune to the corrosive atmospheres created by combustion of high octane fuels. What's more, it's readily applied by fusion to form a non-porous protective facing over the basic valve forging.

But 717 is only one of several specialized nickel-chromium alloys developed and produced by Hoskins. Among the others: Alloy 502 . . . known throughout industry for its dependability on a wide range of heat resistant mechanical applications. The Chromel-Alumel thermocouple alloys . . . unconditionally guaranteed to register true temperature–E.M.F. values within specified close limits. Spark plug electrode alloys which have become universally accepted standards of quality and durability. And, of course, there's Hoskins CHROMEL . . . the *original* nickel-chromium resistance alloy used as heating elements and cold resistors in countless different products.

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Interpretive report by Arthur H. Allen of technical papers and panel discussion on magnetic particle and penetrant inspection, presented at the annual meeting of the Society for Nondestructive Testing, Cleveland, Oct. 22, 1953. Participants and moderators included: Hamilton Migel, Magnaflux Corp.; C. M. Tucker, Aluminum Co. of America; Robert W. Devine, Jr., Timken Roller Bearing Co.; A. D. Van Vessem, Los Alamos Scientific Laboratory; A. Robinson, General Electric Co.; J. E. Clarke, Magnaflux Corp.; T. C. Wilton, Sinclair Refining Co.; D. C. Hart, Ford Motor Co.; William Buckman, Thompson Products, Inc., and Tabor De Forest, Magnaflux Corp.

Improved Tools Expedite Magnetic Particle and Penetrant Inspection

NONDESTRUCTIVE examination of forgings, castings and machined parts for surface discontinuities by means of penetrants that fluoresce under "black light" illumination is practiced widely throughout the metalworking industry. One recent survey of 880 plants disclosed that 228 of these were using some form of fluorescent inspection such as the familiar and simple "Magnalo" and "Zyglo" techniques that were introduced about 12 years ago by the Magnaflux Corp.

Surface defects in ferrous and nonferrous metals occur as minute pores, seams and cracks, often too small to be seen by the unaided eye. Such irregularities may be the cause of premature product failure or result in rejection when revealed by subsequent processing stages. By flowing a brightly fluorescent penetrant over them and then placing the part under near-ultraviolet light (3200 to 4000 Å) they may be detected and interpreted readily by the Zyglo operator. What appears to be a harmless scratch may be a deep crack which could cause failure; conversely, mere surface scratches are not prominently indicated even though they may look like serious discontinuities.

The inspection method lends itself to either continuous or batch-type operation. Briefly, there are four steps: Application of the penetrant by dipping, brushing or spraying; water rinsing and drying; developing by either dusting with dry developer powder or dipping in a colloidal water suspension of developer, and drying; and finally observation under black light in a darkened booth.

While generally employed on the nonferrous metals, such as aluminum, magnesium and bronze, the method also has been adapted to inspection of carbide tools, silver bearing surfaces, tungsten, malleable iron castings, stellite-faced valves, stainless steel linings and welded steel tanks. Zyglo is being used extensively by practically all manufacturers of turbojet engine components.

After the first dip into the penetrant, parts are drained for a period necessary to allow penetration into such flaws as may be present. This requires anywhere from a few minutes to several hours, although the average time is 5 to 15 min. For greater sensitivity and reduced time, Magnaflux recently has introduced what is called a "PE" or "post-emulsification" system in which the original penetrant solution contains no emulsifying agent as does the regular Zyglo. This gives a ten-fold improvement in penetration, and reduces the time for penetration to as little as 3 min. on parts formerly requiring an hour or more. The PE penetrant also contains a more brilliant dye for easier discernability. The emulsifier, applied after the penetrant has worked fully into the flaws, is readily washed off with water after it thickens, but does not remove the penetrant held in the discontinuities.

The PE penetrant appears ideally suited for high-alloy materials and carbides, although its extreme sensitivity requires some revision of interpretation methods. On machined alloy surfaces of 16 rms. smoothness, the new penetrant will give indication of surface cracks

Magnetic Particle and Penetrant Inspection

which are not a cause for rejection. It will readily reveal pin-point discontinuities of 1/64-in. diameter. Manufacturers of jet engine parts report exceptional promise for the new penetrant in their inspection work.

In considering the flourescent penetrant against the "fugitive dye" or visible penetrant, many factors must be recognized – penetrability, visibility, kinds of flaws to be detected, bleed-back and availability of equipment. The two methods, in the opinion of many inspection authorities, supplement rather than compete with each other. In the final analysis, it is the engineer's responsibility to select an inspection method that will give the most dependable test results. Cooperation is essential between prime and subcontractors as regards penetrant inspection and its interpretation.

BLACK LIGHT SOURCES

Proper maintenance of lamps and filters used in penetrant inspection under black light is often overlooked. Lamps are of the mercury vapor type with filters to allow passage of light only in the wave lengths close to 3650 Å. Intensities can be checked readily with standard light meters which, while not providing absolute measurements, are consistent within 8 to 10%. Based on the standard Zyglo penetrant, intensities of 90 foot-candles are suitable for inspection of grinding cracks, 70 foot-candles for heat treating and fatigue cracks, and 50 foot-candles for small cracks in castings.

Light intensities may drop as much as 25% with aging of lamps. Filters must be kept clean constantly, and a frequent check made on voltage variations. A voltage increase of from 110 to 125 will reduce lamp life sharply, perhaps to about 30 hr. It is recommended that in production work, lamps be kept on continuously through a shift, rather than turning on and off as the occasion demands. Excessive heat, bumping and vibration may be other causes of reduced lamp life.

Visual acuity of operators is, of course, important, since inspection under black light is strictly a "seeing"

job. Random checks of inspection results obtained by people unfamiliar with such inspection work were in fairly close agreement in detecting even poorly defined defects where the persons involved had normal vision. The effect of age on visual acuity is something which merits further investigation, as far as black light is concerned.

AUTOMOTIVE APPLICATIONS

Quality control and operating efficiency are facilitated in plants of the Ford Motor Co. by several kinds of nondestructive testing, including radiographic, magnetic particle, surface temper, dye penetrant and ultrasonic measurements. Crankshafts, connecting rods, valve springs, front spindles and other cast and forged parts are checked regularly by the magnetic particle method, effecting a saving of about 20% in inspection costs over former pickling and visual inspection. Among the additional advantages are more positive indication of defects, the elimination of noxious pickling fumes, and generally improved operator convenience.

Inspection for surface temper is a check on abusive grinding practice on steel parts. Martensite in the as-quenched condition is more resistant to attack by an etchant. Thus, the greater degree of temper, the darker the etch. In grinding, heat is generated at the interface of wheel and stock, and if care is not exercised sufficient heat is produced to cause over-tempering of the surface or, even worse, rehardening of the surface to promote grinding cracks. Operators of grinders have become quite familiar with ways to remove visual evidence of grinding burns, but the deleterious effects remain.

As-quenched martensite is brittle and an excessively tempered zone directly beneath does not afford the needed support. Cracks can develop long after grinding, possibly resulting in costly failures. The inspection technique makes use of a 3% HNO_3 etch, rinse, dip in 5% HC1 to clarify the etch, rinse and neutralization. Frequently this is done in the grinding department and has brought much improvement in grinding procedures, wheel selection and choice of coolants.

Fig. 1 – "Zyglo" Fluorescent Indication of Cracks in Weld of Stainless Steel. (Courtesy Magnaflux Corp.)

Ultrasonic measurements are used at the Ford Motor Co. to determine metal thickness in areas where other devices are impractical. Uniformity of wall thickness in cylinder bores, sheet steel gages and thickness of air blast pipes at turns where possible erosion may be encountered all are readily subjected to routine ultrasonic examination.

USE IN FIELD TEST

Field tests of refinery equipment, such as large reactors, by the magnetic particle method have proved to be a valuable inspection tool, not necessarily a cure-all but an important supplement to other techniques. Cracks, slag inclusions and, particularly, poor penetration in welds are shown up clearly by "Magnafluxing". One oil company now has included the method in its specifications for pressure vessels. In a specific test of 2800 ft. of weld (made at the erection site) on a large pressure vessel, cracks were found ranging up to 30 in. in length, some outside the weld area itself. Greatest flaws originated from root openings and from unclosed root faces.

A permanent record of small cracks along weld seams can be made by pressing a strip of transparent adhesive tape over the area after it has been dusted with the iron powder which adheres magnetically to the discontinuity after electrical energization. The tape is then stripped off and transferred to white paper for either photographing or inclusion in record books. The powder that was lodged in a crack comes off onto the tape and discloses the exact extent of the defect.

Ingenious means have been devised to energize large tanks and vessels for magnetic particle inspection in the field. They include the use of two welding generators in series to supply the current which is transferred to the equipment being tested

Magnetic Particle and Penetrant Inspection

(Starts on p. 161)

through "homemade" steel prods or probes. Some tests have been made on structures as far as 105 ft. from the power source. Biggest problem in this sort of work has proved to be the schooling of inspectors in the proper interpretation of indicated defects. Some assistance on this has been provided with displays of typical defects, indicating where they have been found, and conducting group discussions among the initiate inspectors.

Conclusion – No single nondestructive test can solve all inspection problems. A better understanding of all available systems, their potentialities and their limitations, coupled with careful training of inspectors in the interpretation of defects, will go a long way toward sensible utilization of the various test methods. Too often, inspectors are overzealous in trying to discover every possible flaw in a material or part. On the other hand, it has been equally common practice to waive inspection during rush periods with resulting "unforeseen" service failures.

Norwegian Stainless

(Starts on p. 81)

figures average the results on stainless steel delivered during 1953:

Tensile strength	90,000 psi.
Yield point	70,000 psi.
Elongation	31 to 32%
Reduction of area	65 to 68%
Izod impact	70 ft-lb.

The first stainless steel propeller was delivered in 1929; since that time more than 1200 have been made. Figure 3 on p. 82 shows one weighing 15 tons. Ten of these were delivered to a British shipyard during the last 18 months.

Buckets for the Pelton type of reaction turbine have also been one of the foundry's specialties for many years. The same stainless steel alloy as described above is used for these important castings.

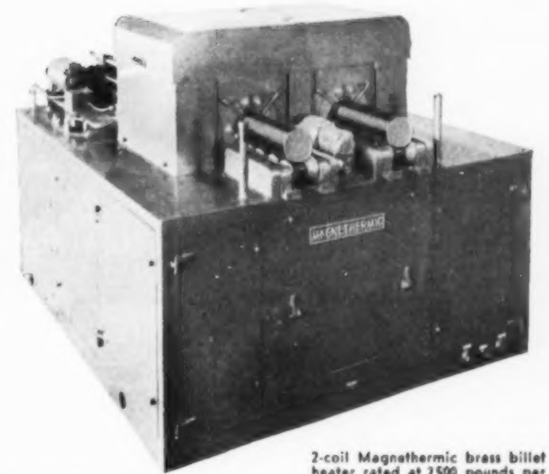
Scrap iron is the main raw material used in the foundry, and it is melted in two top-charged electric furnaces of the Heroult type. In

(Continued on p. 166)

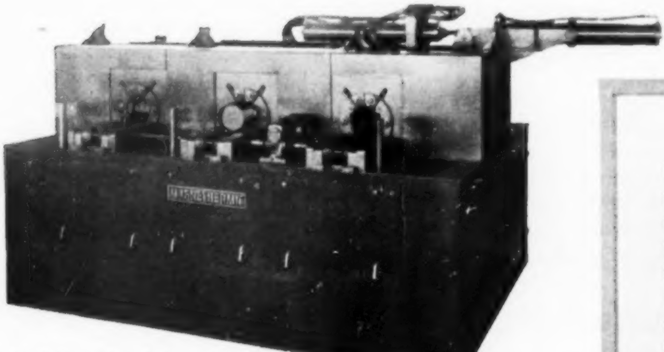
Induction Heaters for Brass and Copper Billets

REDUCE OPERATING COSTS

Magnethermic 60-cycle brass and copper billet heaters, now in operation, prove that they do reduce operating costs. Billets are heated in two or three minutes rather than hours. Temperature control is extremely accurate . . .each billet is discharged at exactly the same temperature. No warm-up time is required. On initial start ups, press the button, and in two or three minutes, heated billets are ready for further processing. No need to schedule billets ahead of time. Not more than three billets are in process at any one time.



2-coil Magnethermic brass billet heater rated at 2500 pounds per hour.



3-coil Magnethermic brass billet heater rated at 10,000 pounds per hour.

MAINTENANCE

Furnace damage is caused by heat. In a typical Magnethermic heater, the heating chamber is a tube 8" in diameter, 24" long, and water cooled for long life. In a conventional furnace, the heating chamber may be 40 ft. long, 8 ft. wide and 3 ft. high. It stands to reason that the latter will require many times the maintenance that the induction coil requires.
Then too, no need to shut down when relining the coil. Operate on the other coils, or put in a spare coil. Coils can be changed in ten minutes and relined in an hour or two.

ALL SIZES

Magnethermic makes a single, two, or three-coil heater for any production requirement needed. All heaters are shipped completely assembled. Installation cost is at a minimum. Working conditions are ideal and floor space is negligible.
Heaters will operate equally well on extrusion billets, piercer billets, or wire bars. If you have a heating problem, let one of our engineers discuss it with you. A letter or phone call will receive prompt attention.

60-CYCLE

MAGNETHERMIC® corporation

3990 SIMON ROAD YOUNGSTOWN 7, OHIO

INDUCTION HEATING

Norwegian Stainless

(Starts on p. 81)

order to eliminate the silicosis hazard completely olivine sand is used for molding. The cement-sand method was first tried in 1929 and since then has been used with great satisfaction for all castings above a certain weight. Pit molding is common for these castings; the molds are to a great extent built up of cores.

For smaller castings, however, the dry sand method is used, the material again being olivine sand with bentonite and clay as bonding agents.

The plant is a typical jobbing foundry and, owing to the intricate shape of most castings, hand molding is used throughout. Many of the workmen have had more than 30 years of experience with the firm.

A/S MYRENS VERKSTED

On a smaller scale A/S Myrens Verksted started to make high-carbon high-chromium alloy castings in 1935 in Oslo, Norway. Its furnace was a Rennerfelt electric arc furnace; molding sand is olivine. Their chosen alloy, containing about 1.0 to 1.2% carbon and 32% chromium, was soon found to be too brittle and hard to machine. It was therefore soon changed to the following approximate composition: 0.10 to 0.25% C, 27% Cr, 4.5% Ni, and varying contents of Mo and Mn.

A/S Myrens Verksted manufactures machinery for the pulp and paper industry, for the herring oil and fishmeal industry, and for the saw mill industry. Consequently, it has appropriate machine shops to supplement the foundry. The principal part of its stainless production, therefore, goes into its own machinery destined for the pulp and paper industry. Figure 4 on p. 83 shows some parts molded and cast in olivine sand.

An interesting sidelight on conditions in Norway ten years ago exists in the fact that during the war civilian transport had to rely almost exclusively on trucks driven by a gas producer connected to the machines – there being no gasoline available. The heat resisting parts of this producer were made of "Termacid", an alloy of approximate composition mentioned above. It has good heat resistance up to 1100° C. (2000° F.)

Thomas Steel in Europe

(Continued from p. 96)

Oxygen Enriched Blast – Really remarkable results have followed oxygen enrichment of the blast[7] toward the end of the blow, which became economically feasible some years ago thanks to new techniques for mass production of oxygen. With blast having about 30% oxygen (or in any event not over 40%, which would make the operation more difficult to control and would cause an excessive wear of the lining) it is possible to reduce the final nitrogen content of the charge from 0.010 or 0.012% (which might be the mean value otherwise) down to 0.008%, for instance.

However, this enrichment, which reduces the volume of gases going through the bath and the amount of heat extracted as they go through it, changes the thermal balance of the operation, increases the temperature and makes available a certain number of thermal units which have to be absorbed with cold additions to avoid overheating the metal. These additions may be made of scrap, and this process has been used since 1939 at the Maximilien works at Sulzbach, Bavaria. But scrap is even scarcer in Europe than in the United States, so it is more logical to keep it for the openhearth or the electric arc furnaces, and to reduce the nitrogen content still further by using a certain amount of iron ore and mill scale. The mean nitrogen content could thus be lowered, for instance, from 0.008% with oxygen and scrap, to 0.006% using oxygen and ore.

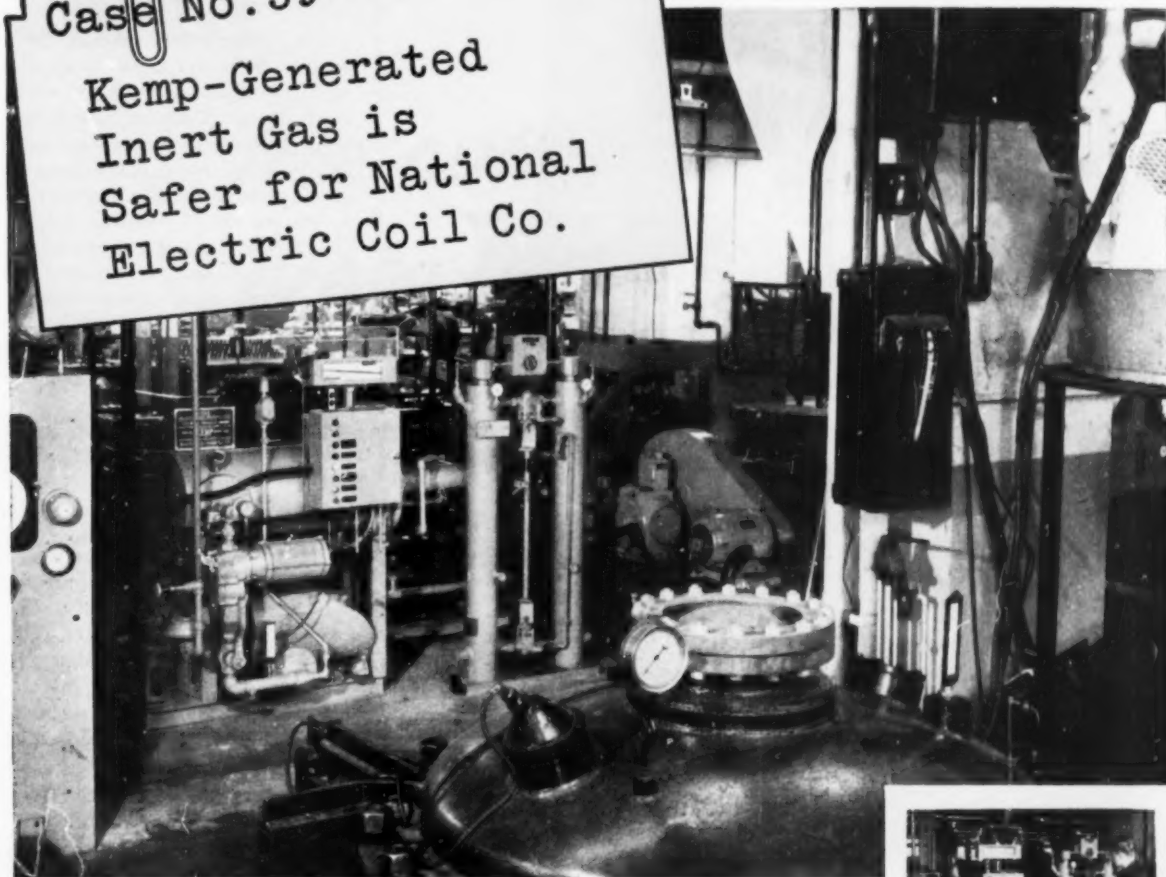
Replacement of part of the lime addition with limestone will further reduce the partial pressure of nitrogen by evolving CO_2, and consequently will further reduce the nitrogen content, making it possible to obtain analyses of 0.005 to 0.006%, equal to those for a regular openhearth steel.

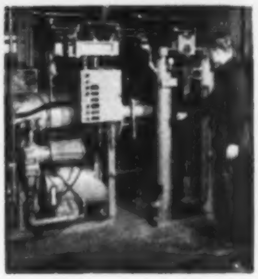
To drive the nitrogen down still further it is necessary to eliminate nitrogen entirely from the blow. But pure oxygen cannot be used in a bottom-blown converter since the refractories would not stand it. Therefore another inert gas must be substituted for nitrogen. This has been done successfully in Belgium either with water vapor or with CO_2.

(Continued on p. 170)

Case No. 59

Kemp-Generated Inert Gas is Safer for National Electric Coil Co.





Mr. Wm. C. Graessle, of the engineering department, checking the operation. Generator features the Kemp Carburetor, part of all Kemp equipment, to deliver complete combustion . . . without waste, without tinkering.

How National eliminates danger of explosion . . . cheaply and conveniently

National Electric Coil Co., Columbus,Ohio, impregnates electric coils and windings by forcing in a hot sealing compound with inert gas under pressure. Formerly, the Company used air under pressure, but this created an explosion hazard. National then switched to CO_2 generated by melting dry ice. Although this decreased the danger factor, it was an extremely expensive operation and very inconvenient. To modernize this process and cut costs, National installed a Kemp Gas Generator, Model MIHE.

Kemp Solved the Problem—and More

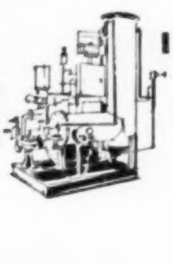
Now National's Kemp installation delivers a completely satisfactory inert—eliminating any danger of explosion. And it delivers it at a *much lower cost* than the former generating method. In addition, Kemp supplies the gas at the rate required, plus a reserve for storage. As for convenience, the company considers their unit entirely automatic—it is practically never touched. According to Mr. D. E. Stafford, Chief Engineer, "It just sits there and operates."

Kemp Can Solve Your Problem Too

Every Kemp Generator is engineered for fast-starting, easy operation that saves both *time* and *money*. Kemp equipment delivers a chemically clean inert at a specific analysis . . . without fluctuations regardless of demand. And every Kemp design includes the latest firechecks and safety devices. For convenience, safety, and cleaner, more dependable gas—specify Kemp.

For more complete facts and technical information, write for Bulletin I-10 to: C. M. KEMP MFG. CO., 405 East Oliver Street, Baltimore 2, Md.

KEMP OF BALTIMORE



INERT GAS GENERATORS

CARBURETORS • BURNERS • FIRE CHECKS
METAL MELTING UNITS • ADSORPTIVE
DRYERS • SINGEING EQUIPMENT

Thomas Steel in Europe

Starts on p. 94)

The water vapor process (60% oxygen, 40% water vapor) is applied on a commercial scale at the works of l'Espérance Longdoz, near Liège, Belgium. Nitrogen contents are regularly obtained much below those of good openhearth steels; they may be as low as 0.002%. Another Belgian plant in the Hainaut area is working with CO_2 and oxygen mixtures.

Lastly, the Austrian steel works at Linz and Donawitz, refining a low-phosphorus, high-manganese iron, injects pure oxygen through the top of the converter by a lance ending some distance above the bath's surface. The vessel is converter-shaped but has a solid bottom[8]. In this practice the cooling additions must, of necessity, be very considerable.

The Mannesmann plant at Hückingen, in the Ruhr basin, has successfully tested the application of the same process in a small 3-ton converter, using phosphorus irons. It has been possible, providing ore additions are made correctly, to obtain simultaneously complete dephosphorization and decarburization[9].

A whole range of various possibilities is therefore offered to Europeans at the present time by the Thomas steelmaking process. They have at their disposal processes enabling them to make low-nitrogen steels which, thanks to temperature control and the use of a second slag, may also be very low in phosphorus. In brief, these processes are as follows:

1. Conventional Thomas process, giving a nitrogen content generally over 0.010%.
2. Ore, mill scale, or limestone additions, and blowing with ordinary air, affording nitrogen contents of 0.007 to 0.010%.
3. Ore, mill scale, or limestone additions, and use of oxygen-enriched air, affording nitrogen contents of 0.005 to 0.007%.
4. Use of mixtures of oxygen with water vapor or CO_2, affording nitrogen contents below 0.005%.

LOW-NITROGEN STEELS

Steels with a nitrogen content of 0.008 to 0.010% have physical and fabrication properties intermediate between those of ordinary Thomas

(Continued on p. 172)

Thomas Steel in Europe

(Starts on p. 94)

basic converter steel and those of basic openhearth steel.

Basic converter steels having about 0.006% nitrogen – that is, of the same order as openhearth steel – and fairly low in phosphorus and sulphur, act about the same as openhearth steel in wiredrawing or deep drawing practice. With 0.002 to 0.005% nitrogen, the properties of the steel, especially as to aging, may even exceed those of a rimming openhearth steel.

The purity of the steel obtained increases from the beginning to the end of the above list, while the cost also increases. It is essential, therefore, to choose for each individual fabrication the process best fitted. That is why in Belgium, where the production of openhearth steel is very small, they are especially interested in the use of water vapor or carbon dioxide, for steels intended for sheet. In France, where the production of openhearth steel is more developed, more attention is paid to the intermediate processes. Particularly, M. Leroy has recently described at the Autumn Congress of the French Metallurgical Society, held in Paris in October 1953, a special blowing technique in which the use of a peculiar flowmeter, called a "volume-debit graph", enables the operator to vary the oxygen flow at will during the blow.

Under these conditions, one can maintain a mean oxygen content of the wind of at least 30% during the over-all operation, and at the same time avoid, at the critical moment when spitting occurs, the use of a high oxygen ratio which would be likely to favor it.[10]

Oxygen has already gone far beyond the discussion stage in Europe. Several German steel plants already have oxygen plants at their disposal. Two Belgian plans in the Liège district serve three steel plants.

In France, a steel plant supplying a continuous strip rolling mill has just built its own oxygen plant. Another one, which is to supply oxygen to four steel plants of the Longwy district, is under construction.

One further important consideration remains to be mentioned. When the blast is enriched in oxygen the converter can handle iron with a

(Continued on p. 174)

Thomas Steel in Europe

(Starts on p. 94)

phosphorus content below that required for regular Thomas operation, whose composition would not attain the correct thermal balance with natural air. This fact will probably increase the interest of British steelmen, who usually use iron with 1 to 1.5% phosphorus instead of the usual 1.8% of the Continent. The capital tied up in plant per ton of yearly production is indeed much lower for the Thomas process than for the openhearth. Thus an entirely new economic balance may well be in the making for the years not too far distant in the future.

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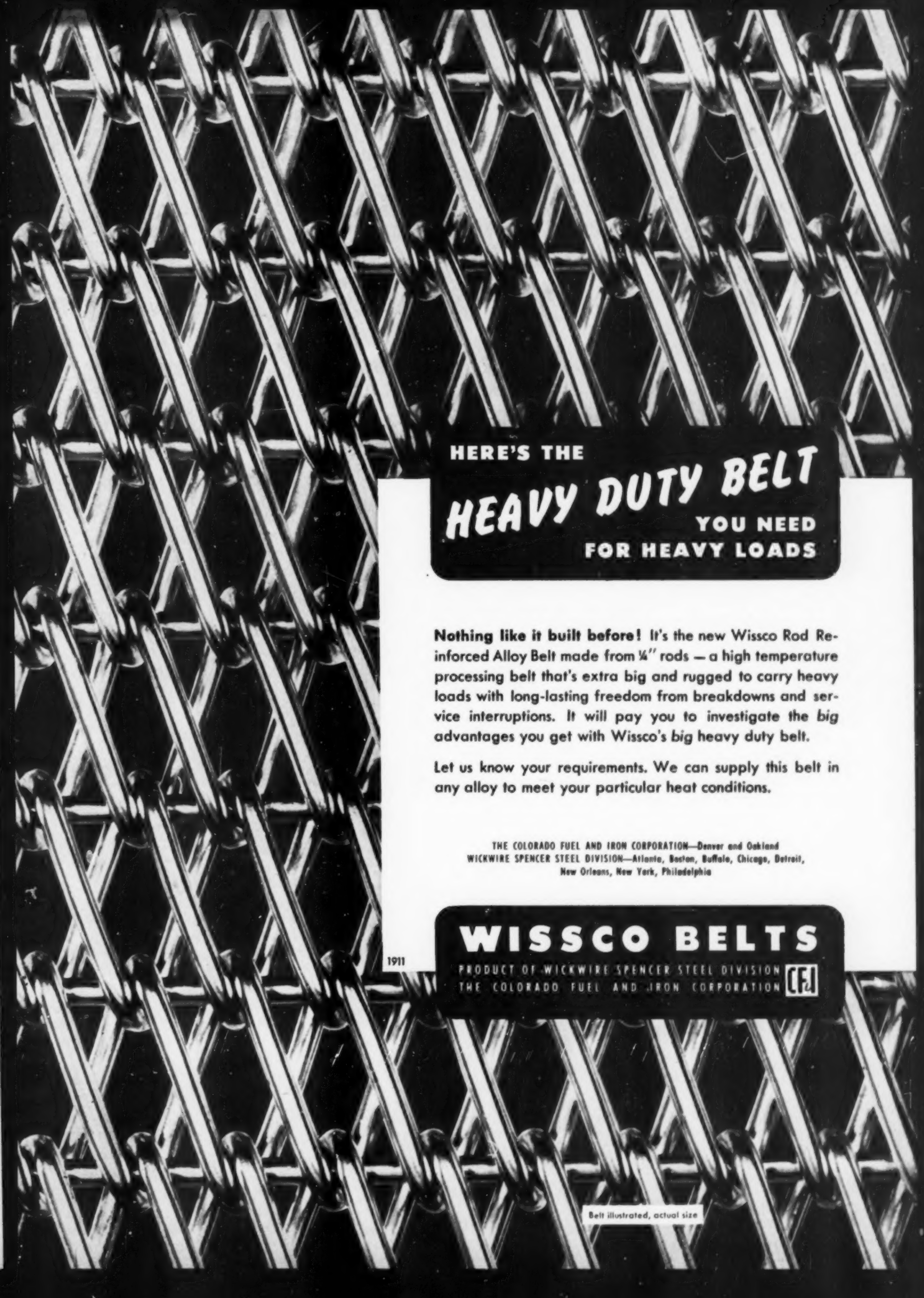
(Continued on p. 176)



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Thomas Steel in Europe

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Authors... IN THIS ISSUE

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Born in Fribourg, Switzerland, he has the degree of Doctor of Technical Sciences from the Swiss Federal Institute of Technology at Zurich. He is director of the Swiss Acetylene Society at Basel, and has edited the Swiss *Welding Journal* since 1946. In 1947 he became professor of welding technology at the Swiss Federal Institute of Technology, succeeding his father, the late Prof. C. F. Keel.

Charles Keel is a member of the governing council of the International Institute of Welding and president of its committee No. 1 on Gas Welding. He is also president of a subcommittee of the Commission Permanente International de l'Acétylene. In 1951 he acted as chairman of study group No. 5, "Welding and Joining", which attended the first World Metallurgical Congress in Detroit.

His indoor hobbies are stamp collecting and amateur radio (call signal HB9P).

Tom Bishop

Sheffield-born, Tom Bishop received a metallurgical degree from his home-town university. He served in the British Army from 1939 to mid-1946, being among those who survived the ill-fated expedition to Norway. He became captain in the Royal Electrical and Mechanical Engineers, serving also in Iceland and Germany. He specialized in radar work, and tank armor development. He was a member of CIOS and BIOS teams which investigated German metallurgical works immediately after their surrender. After the war, he joined Industrial Newspapers, Ltd. (London), and is now editor of *Metal Treatment and Drop Forging* and metallurgical editor of *Iron and Coal Trades Review*. He is an associate of the Institution of Metallurgists, and a member of the Iron and Steel Institute, Society of Chemical Industry, and Institute of British Foundrymen.

Wilhelm Ruttmann

For the past six years in charge of research into inorganic material for Bayer Dye Works at Leverkusen, Germany, he has had the responsibility of representing the owner in the design, fabrication and erection of the superpower steam plant described on p. 116 of this issue. He is a Bavarian who graduated from Darmstadt University in 1930. He has spent his working life in the testing of materials in such institutions as the National Materials Testing Bureau, Krupp's Laboratories in Essen, and Siemens-Schuckert in Berlin.

Rudolf Schinn

One of the co-authors of the article on the record-breaking steam power plant, studied at Stuttgart and Berlin-Charlottenburg and graduated from the latter in 1935. All his working life has been spent in Siemens-Schuckert's Works, and since 1940 he has been in charge of the materials testing laboratory of the turbine plant at Mulheim, Ruhr.

Herbert W. Buchholtz, the third author of the article on p. 116, has been director of the research institute of the Mannesmannrohren-Werke in Duisburg-Huckingen since 1937. He studied at Berlin-Charlottenburg and received his doctor-engineer degree from the Technische Hochschule in Braunschweig in 1928.

C. L. Clark

Metallurgical engineer in special steel developments at the Timken Roller Bearing Co., Canton, Ohio, Dr. Clark is the author of the book "High-Temperature Alloys". Following graduation from the University of Michigan, (B.S.E., 192[illegible]; M.S.E., 1926; and Ph.D., 1928), he remained with his alma mater as research engineer in metallurgy, specializing in the development and application of high-temperature steels. Dr. Clark has been asso-

ciated with the Timken Roller Bearing Co. since 1940, starting as research metallurgical engineer. He is a member of the American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Society for Testing Materials, National Association of Corrosion Engineers and the American Society for Metals, as well as numerous technical committees and honorary scientific fraternities.

Bo Michael Sture Kalling

Since 1945 he has been director of research and development of Sweden's largest metallurgical enterprise, Domnarvet Iron and Steelworks of Stora Kopparbergs Bergslogs AB, has directed investigations which have resulted in several unique commercial processes and has contributed largely to current metallurgical literature. He graduated from the Royal Institute of Technology in Stockholm in 1914 and was in active metallurgical work until 1931, when he became professor of metallurgy at his alma mater – a post he held for a decade with such distinction that he is known affectionately in the industry as "Professor".

Daniel J. Murphy

Until recently as head of the Pitman-Dunn Laboratories of Frankford Arsenal, he coordinated many of the research programs concerned with the development of arms and ammunition for the Army Ordnance Corps, while being directly involved in the work of the laboratories' metallurgical staff. A graduate of West Point in 1935, he received a M.S. in engineering from Massachusetts Institute of Technology in 1939 and a Ph.D. in metal physics from Columbia in 1952. Now serving with the Army Ordnance Corps in Japan, he has observed first hand the metallurgical activities on which the article on p. 67 is based.

Paul Brenner

Director of research of the Vereinigte Aluminium-Werke A. G. and Vereinigte Leichtmetall-Werke G.m.b.H., both in Bonn, principal producers of virgin aluminum and semifinished light metals in Germany. He is also professor of industrial metallurgy and application of light metals at the University in Hanover. He graduated as a Doctor Engineer from the University in Berlin-Charlottenburg in 1928, and from 1923 to 1936 he was chief of the material department of the Deutsche Versuchsanstalt fur Luftfahrt (German Research Institute for Aircraft). He worked as a scientist at the Royal Aircraft Establishment in Farnborough, England, from 1946 to 1948. Professor Brenner is president of the "Deutsche Gesellschaft fur Metallkunde", the German Society for Metals.

Alberto Oreffice

After graduation as doctor engineer from the University of Padua, he entered the Italian army and served as an engineering officer during all of World War I. He then entered the FIAT Ferriere Piemontesi in Turin (FIAT's steel works) in 1919 as engineer, and was promoted in 1922 to be chief engineer of the springs department. This position he held until 1950, when he became chief engineer and consulting engineer of FIAT's central laboratories for research and tests in Turin. Dr. Oreffice has contributed numerous "Letters to the Editor of *Metal Progress*" since 1939. He is recognized throughout Europe as a leading authority on spring materials, springmaking, and their heat treatment and surface treatment.

John Sissener

The consulting engineer and Scandinavian representative for the International Meehanite Metal Co., Ltd., in London, he is also president of the Norwegian Foundrymen's Technical Association. He was a leader of the first Norwegian foundry productivity team to the United States in 1950, and under the United Nations Technical Assistance program was foundry expert to Jugoslavia in 1951 and to Israel in 1952. Mr. Sissener is a graduate of the Technical University of Trondheim, Norway, and in 1921 was associated with the late Professor Oberhoffer in Aachen, Germany. He instigated the production of stainless steels in olivine sand at A/S Myrens Verksted, Oslo, in 1935, and is the author of various books concerning foundry technique and foundry metallurgy.

Metallic Materials for a Steam Power Plant Operating at 1130° F.

(Starts on p. 116) scale resistance in the operating temperature range against both combustion gases and steam. It is usually assumed that the combustion gases are oxidizing rather than reducing, since that is the state of affairs usually sought for fuel economy. To settle the question of scaling in steam, comparative scaling tests on ferritic and austenitic steels were carried out. The investigation covered a soft carbon steel St. 35 (0.11% C.), three of the low-alloy ferritic materials of Table I (No. III, V and VI, the latter without molybdenum) and four austenitic Cr-Ni-Fe alloys. The tests were made at two temperatures, 550 and 630° C. (1020 and 1165° F.).

Results for the ferritic steels may be summarized in mm. penetration per year in the table below:

All the stainless tested contained less than 0.10% C. One was steel No. X of Table I. The others were 18-9 Cr-Ni, stabilized with columbium; 18-9 plus 1% W, stabilized with titanium, and 18-10 plus 2% Mo stabilized with columbium.

Corrosion losses of all four of these steels at 550° C. were on the order of 0.10 mm. per year in steam, either with or without ammonia. At 630° C. the 18-8 W, Ti was most resistant (0.10 in steam, 0.13 in steam plus NH_3), and the 18-8 Mo, Cb was least resistant (losing 0.31 mm. per year in steam and 0.36 in steam plus NH_3).

The series of tests showed that the rate of attack on the worst of the austenitic materials was less at 630° C. than that of the best of the ferritic

(Continued on p. 182)

	(At 550° C. (1020° F.)		(At 630° C. (1165° F.)	
Steel	Steam	Steam Plus NH_3	Steam	Steam Plus NH_3
St.35	0.95	0.46	2.36	3.90
III	1.32	0.72	6.40	5.10
V	1.22	0.90	3.35	4.50
VI (less Mo)	0.60	0.40	—	—

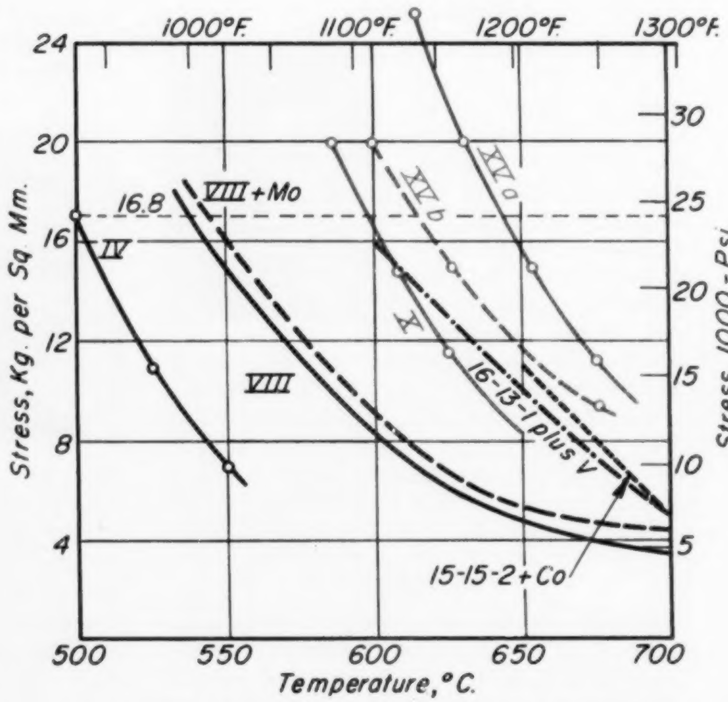

Fig. 6 – 100,000-Hr. Tensile Strength of Turbine Steels, Showing Improvements in Austenitic Alloy X of Table I by Adding Boron (XVb) and Then by Cold Working 15% (XVa)

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W. H. KIRBY, Honeywell Supplies Man in the Los Angeles area, shows Mr. Frank Edmunds of Lever Bros.' Los Angeles plant why the Brown butt-welded thermocouple is faster-responding—because its hot junction has smaller mass, and is curved to prevent heat dissipation through the insulators.
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First in Controls

Steam Power Plant

(Starts on p. 116)

at 550° C. Ammonia additions of about 5 mg. per liter to the steam did not alter these results materially, but salt increased the rate of attack considerably. The boiler water was therefore freed from salt as far as was commercially feasible.

The turbine casing runs as hot as 580° C. (1075° F.) on the interior surface. A ferritic steel with normal chromium content (under 5%) is strong enough for this application, but its scale would flake off objectionably. A ferritic and scale resistant steel with about 5% Cr was ruled out because the scale resistance would be gained only with a corresponding drop in stress-rupture properties. To avoid the difficulties involved in casting such a large austenitic steel item, it was decided to protect the surface of this part by aluminum diffusion. The casing was therefore covered with aluminum powder and held at 1000° C. (1830° F.) for 40 hr. Figure 5 on p. 120 shows a section through the diffusion zone after heating for 14,470 hr. in air at 600° C. (1110° F.). The original surface AB is attacked down to line AC which illustrates how durable the metal is.

Wear – One further surface problem is the wear of moving parts, such as the surface of valve spindles. Tests were made to determine whether nitrided austenitic steels would retain their hardness after long stay at 600° C. (1110° F.). Such tests were carried out to 28,000 hr. The heat treatable steels No. XIV and IV lost their hardness within 200 hr. by continued diffusion of the nitrogen into the core of the stock. Of the austenitic steels, the titanium-containing steel No. XIII was best. The original nitrided surface had a Vickers hardness of 990; after 100 hr. at temperature it was 930; after 1000 hr. it was 775; after 10,000 hr. it was 600 and at the end (28,000 hr. or 3 years) it still had a hardness of 460, although the nitride layer was very thin.

Hard facing alloys, tested in an experimental valve, showed up poorly. Colmonoy (72% Ni, 16% Cr, 3.7% B) broke down after 1500 hr. Stellite 50 (56 Co, 27 Cr, 14 W, with over 2% C) broke down after 1000 hr. Both these alloys scaled beyond any permissible limits at 600° C. Stellite 40 (65 Co, 27 Cr, 4.5 W, 1.2 C) lasted well, but its low coefficient of expansion approximates that of ferritic steels and this must be considered when used in conjunction with austenitic steels.

WELDING PROBLEMS

Fully Austenitic Weld – Autogenous welding was not even considered because of the danger of carburization and its attendant grain-boundary attack. Despite American experience which indicated that "hot cracks" can be avoided only when the bead metal contains 4 to 7% ferrite, a fully austenitic weldment was sought. (The chief reason for this was that we wished to avoid any possibility of embrittlement due to the precipitation of sigma phase.) This was obtained by welding with electrodes of similar composition to the base stock and specifying beads that were stable against grain-boundary attack and free from hot microcracks. Experience has shown it difficult to fulfill all these requirements with very low-carbon chromium-nickel steel electrodes. Bohler Fox "CN 1613" electrodes did, however, fill the bill here.

(Continued on p. 184)

Steam Power Plant

(Starts on p. 116)

In producing these rods special attention was paid to obtaining a ratio of carbon to tantalum plus columbium which would be sufficient to prevent grain-boundary precipitation in the final deposit. Plates up to 1 in. thick and castings up to 1.50 in. were welded without cracks and with satisfactory grain structure.

Toughness – In the ideal case the properties of the weld bead and the base stock would be the same. Long-time stress-rupture tests (more than 10,000 hr.) on steel VIII, welded with the electrodes described above, gave results about 75% that of the unwelded stock. These results were obtained on specimens that were welded and later milled off so that the extra thickness of the weld bead did not contribute to the strength of the bond.

The impact strength of the bead or of the weldment as a whole was generally lower than that of the base plate. The lowest curve in Fig. 4 (p. 120) gives results of long heating at 650° C. (1200° F.). On weldments there was a drop in impact strength of 1 to 2 kg-m. per sq. cm. at 2000 hr., so that the net design value was about 5 kg-m. per sq. cm., since a further drop seemed improbable up to virtually 10,000 hr.

Quartz Back-up Rings – Because of the small inside diameter of some of the tubes (0.6 to 1.6 in.), any reduction of the cross-sectional area at welded joints from flash or back-up rings was to be avoided at all costs. For welding in the shop a quartz back-up ring was used, which did not remain in place after welding but cracked because of its low coefficient of expansion compared to the tube. The loose shards were readily blown out.

This procedure is not applicable in erection, since a quartz ring would be broken before welding because of unavoidable pinching or squeezing while getting it in place. Accordingly, copper rings that could easily be pushed in and out were used in erecting straight tubes. A mild steel back-up ring was used in tube bends and this was later dissolved out with nitric acid, a procedure which caused no special problems since the boiler was flushed out with acid to begin with. Complete removal of the ferritic back-up ring was guaranteed by magnetic inspection.

Austenite to Ferrite – Because of previous unfavorable experience with austenitic welds of high-temperature ferritic tubes, we wanted to make doubly sure of the joint between the ferritic and austenitic parts of the superheater. This joint was therefore designed as a bolted and gasketed joint which obviously lay outside the heated zones. In the meantime Mannesmann and the Rheinische Rohrenwerke have developed space-saving rolled and welded joints, respectively, which are now undergoing fluctuating temperature tests.

TUBES AND CONDENSER

The austenitic tubes for the boiler and the hot steam lines were made out of round ingots forged or rolled. The trap tubes with 3-in. outside diameter and 0.40-in. wall, and the condenser tubes with 3⅜ to 8-in. outside diameter and ⅜ to 1⅜-in. wall, as well as the hot steam lines, were hot pierced and finally quenched. The superheater tubes with 1-in. outside diameter and 0.20-in. wall were processed from warm rolled or forged billets by cold rock-rolling followed

(Continued on p. 186)

Steam Power Plant

(Starts on p. 116)

by an intermediate quench and then cold drawing to size in a number of passes with a final quench. The total requirement of austenitic steels for boiler and conduits was 120,000 lb., 65,000 lb. going into the boiler alone.

The connection between boiler and turbine was not a single tube but rather a bundle of 28, each having an outside diameter of 2⅛ in, and a ½-in. wall. The individual tubes were assembled in four groups of seven tubes, spaced around the outside of a forged jig or core.

Alloys for Even Higher Temperatures – Some extensive and successful work has been done with the object of discovering simple modifications of the chromium-nickel austenitic steels which would have considerably higher rupture strength at 100,000 hr. than alloy No. VIII which was used so extensively in the 1130° F. steam plant described above. Some of the interesting results are summarized in Fig. 6 on p. 180, showing the 100,000-hr. tensile strength for high-temperature boiler and turbine materials.

The ferritic Cr-Mo-V steel (No. IV of Table I) is commonly used for wheels and bolts for steam turbines operating at 500° C. (930° F.). Its 100,000-hr. rupture strength at 500° C. is shown to be 16.8 kg. per sq. mm. or 24,000 psi. Its strength at 500 to 550° C. is matched at temperatures 50° higher by No. VIII of Table I (16-13-1 Cr-Ni-Cb).

The addition of 2% Mo to this analysis has its first considerable effect above 650° C. (1200° F.) especially in tests at 10,000 hr. With 1% columbium, hardening somewhat with 0.15% N_2 and cold working the metal brings alloy No. X, which moves the stress-temperature curve another 40 or 50° C. to the right into higher temperature. This was used in the 1130° F. plant for turbine wheels and buckets, being as strong at 600° C. as old steel No. IV is at 500° C. The long-time yield and tensile strengths of steels 15-15-2 plus Co,* and 16-13-1 plus V† are increased at 650° C. (1200° F.) considerably by precipitation hardening

(Continued on p. 188)

*Analysis: 15% Cr, 14% Ni, 1.5% Mo, 2% Co, 0.8% V, 0.8% W.
†Analysis: 16.8% Cr, 13% Ni, 1.4% Mo, 0.8% V, 0.07% N.

Steam Power Plant

(Starts on p. 116)

with special carbides and nitrides (W, V, Ti or Mo) but only slightly at 700° C. (1290° F.).

These steels are quite free from embrittlement and have good weldability with Cr-Ni-Co electrodes, but the scale resistance of the two steels containing vanadium does not extend beyond 700° C.

However, the use of the precipitation hardening Cr-Ni austenitic steels permits an increase in operating temperature to 630° C. (1165° F.).

Figure 6 also shows the notable high-temperature strength of alloy XV, much like alloy X. Alloy XV is a low-carbon, 17-13-2 Cr-Ni-Mo steel, stabilized with 1% columbium, and containing a few hundredths of 1% of boron. The curve for alloy XV*b*, in comparison with that for Alloy X, shows the advantage of hardening with boron rather than with nitrogen, while the curve for alloy XV*a* indicates the notable improvement in high-temperature strength of the same alloy after a proper schedule of cold work involving 15% deformation.

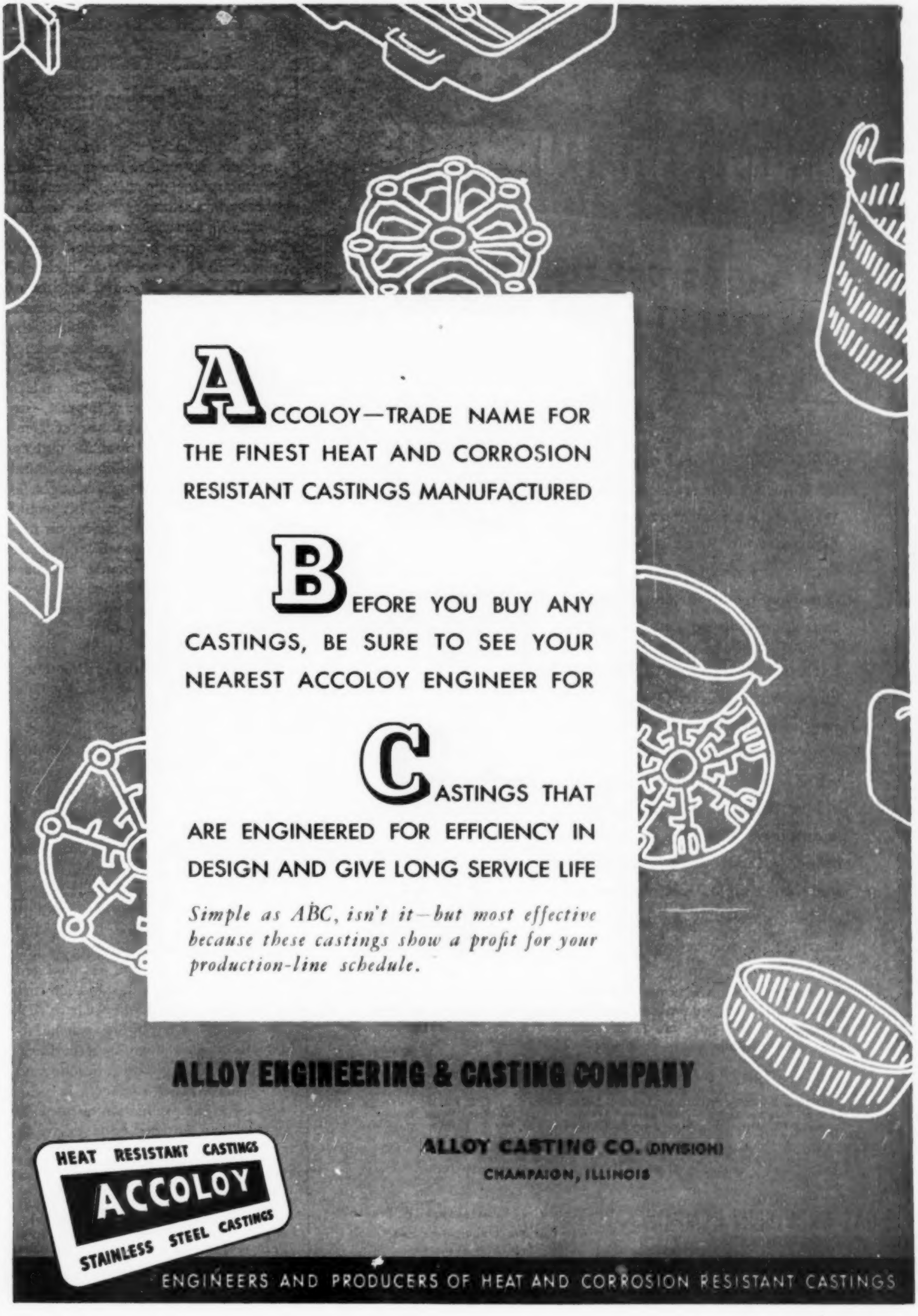
Use of such an alloy would seem to warrant operation at another 40° C. increase in temperature over our present installation – that is to say at 650° C. (1200° F.).

British Advances in Metals, Fabrication and Applications

(Continued from p. 104)

An interesting technique for forging, upsetting or plain billet heating has been developed by Omes Ltd., of London, useful for both ferrous and nonferrous metals. Essentially, material is heated in this process by a low-voltage current passed through the billet itself. It is being used for the manufacture of turbine blades and axial compressor blades, precision forged from centerless ground bar or rolled airfoil section. The bar is clamped hydraulically in a simple vise which forms the second electrode. Anvil and vise serve to carry the current through the portion of the stock to be upset or otherwise shaped. The machine is automatic

(Continued on p. 190)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British Advances in Metals, Fabrication and Applications

(Starts on p. 101)

in operation and, as the temperature necessary for upsetting is reached, the hydraulic ram feeds the bar forward. The anvil is mounted upon a slide and can be retracted slowly during the advance of the hydraulic ram. When the required amount of metal has been upset, movement stops, the vise is opened and the headed bar is transferred to a forging die for final shape.

Cast milling cutters – There is a considerable amount of interest, currently, in the manufacture of complicated tools such as milling cutters, forging dies, extrusion dies and plastic molding dies which might be cast very close to form. This would result in a very great saving in machining time and would eliminate large quantities of blanks and bars from warehouse stock, since necessary melting material could be ordered when desired.

For example, Ludwig von Roll'schen Eisenwerke of Solothurn, Switzerland, has made many claims of excellence for cast milling cutters of two interesting analyses trade-named "Rollodur", the first containing 13% Cr, 10% W and 1.5% C, and the second containing 13% Cr, 4% W and 1.4% C.

In England B.S.A. Tools Limited* has discovered that almost any composition of steel can be melted and cast in investment molds – anything from case hardening types to tungsten types of the hot-die and high speed steels. Castings up to 250 lb. can be produced at the moment and the process is adjusted such that a very fine grain size, similar to that in an equivalent forging, can be attained in such investment castings.

The results to date are good and it is believed that a new era is being opened in the production of intricate cutting and forming tools.

*Editor's Note — In a recent issue of *Metal Progress* the Editor ignorantly translated B.S.A. as "British Standards Assoc." — about as far from actuality as imaginable. B.S.A. really stands for "Birmingham Small Arms", although it is never spelled out in England, where a B.S.A. bicycle is, simply, a B.S.A. bicycle!

Supplement on Weldability

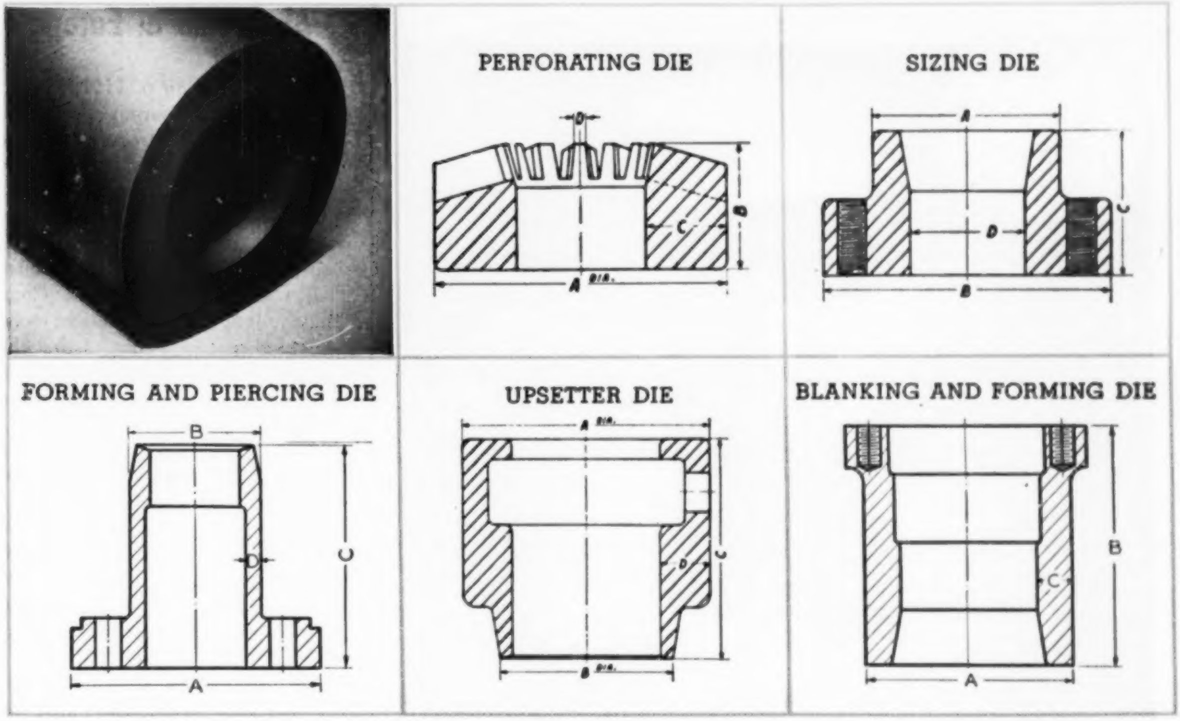
At the Editor's request, Professor Keel has amplified certain items in his article on "Weldability of Steel as It Is Considered by Swiss Engineers" and has promised a brief article which we can print in a month or two on the Schnadt tests for estimating the resistance of steel to brittleness and multi-axial loads.

Steels Aldur 50 and 58 used for penstocks are made in Austria, the first being a high-silicon mild steel (C <0.20, Si 0.45, Mn 0.95) with 70,000 to 85,000 psi. ultimate strength. Aldur is a 0.20% carbon steel with the same silicon but 1.40% Mn and 0.35% Cu. Its ultimate strength is 82,500 to 96,500 psi., 57,500 min. yield, 22% elongation in 5 dia. Both must pass a 6 m-kg. impact test after 10% cold work and aging 30 min. at 480° F.

The Kommerell test has been described in Research Supplement to *Welding Journal*, July 1946. A plate sample whose size is proportional to its thickness (for example, 15 in. by 6 in. for a 1-in. plate) has a semicircular ⅛-in. groove cut lengthwise down its center and a bead deposited in about two-thirds its midlength. The sample is bent slowly, weld down, and the angle is noted when cracks first appear and when they propagate into the base material. Nature of the fracture surface is also noted. In the example chosen the bending die has a rounded end and is 3½ in. thick; supporting pins are 4 in. diameter and the clear distance between them is six times the plate thickness. Swiss welding engineers follow the Austrian standard M 3052.

The "quality coefficient" specified for the steels used in the Tannwald Bridge is the product of 0.01 times the tensile strength (in kg. per sq.m.) and the percent elongation on 5 diameters.

To the Editor's comment that steels St. Z1 and St. 37.161 used in this bridge appear to be interchangeable judged from analysis and properties, Professor Keel says that St. Z1 was preferred because, as a fine-grained openhearth steel, it fulfilled some additional tests such as lower sensitivity to cracks and aging effects (judged by Schnadt tests at 5° F.) and better plastic properties (elongation and reduction of area).



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Aluminum in Europe

(Starts on p. 112)

alloys, since they permit a very uniform transfer of stress across the joint. Stress concentrations (which, for example, are present in riveted joints – and the rivets also severely impair the strength of those materials because of their high notch-sensitivity) can thus be avoided. Comparative fatigue tests with light metal structural members showed that the riveted assembly failed at 300,000 to 700,000 cycles while the resin-bonded assembly held out for 2,100,000 to 4,500,000. The unavoidable loss in tensile strength which must be allowed for in age hardening alloys because of the effect of the heat during welding or brazing is no factor, since the temperatures to which resin-bonded joints are heated are so low that the mechanical properties are not affected.

This process was used for the first time in aircraft construction after the War. "Redux", a phenol resin, was used for this purpose. More than 100 aircraft of the deHavilland "Dove" type have made extensive use of resin-bonded joints, and their reliability has been proven under severe service conditions in Australia and Africa. The structures of the deHavilland "Comet" aircraft, the "Canberra" jet bomber and the "Bristol 175" transport aircraft are to a great extent resin-bonded. Considerable savings in weight and better aerodynamic properties also result.

The resin-bonding process is also entering other fields to an increasing extent, such as vehicle construction, the manufacture of windows and furniture, as well as the joining of machine parts. Two of the bonding materials most commonly used for these purposes are "Araldit", an ethoxylin resin, and "Desmodur-Desmophen", a poly-addition resin. Lap joints made with them have a shear strength of about 2000 psi.

APPLICATIONS

The fields of application of light metals have become so varied in the postwar period that they could not be fully enumerated in the space available. Therefore only some of the new or especially interesting examples will be mentioned.

(Continued on p. 196)

Aluminum in Europe

(Starts on p. 112)

In the effort to increase coal production in Germany we are using light metals for mine timbering (Fig. 1, p. 114). Heavy work of the miner can be considerably lightened since the aluminum props and caps weigh about 40% that of corresponding steel members. Further advantages arise from the favorable frictional properties under bearing loads, the high corrosion resistance, and the safety from sparking.

After the first light metal bascule bridge was built in 1948 in Sunderland, England, a new one was designed for the port of Aberdeen, Scotland, using experience gathered during the construction and use of the first bridge. This bridge has a span of 100 ft., a roadway 22 ft. wide, and a railway track to the side of the road. On both sides of the main girders are 5-ft. cantilevered footpaths. The light metal rivets, up to ⅞ in. in diameter, were driven cold.

Another light metal footbridge is the graceful one in Düsseldorf illustrated at the head of this article. It has a span of 180 ft. and a width of 26 ft.; its total weight is 24 tons. It would weigh 70 tons in steel, minus the paint.

Great progress has been made in the use of light metals in transportation equipment. It became customary to use light metals for postwar passenger ships, especially topside structures like bridges, funnels, davits, and lifeboats. Weight was saved, and stability improved due to the lower center of gravity. Even in river boats, lower weights decreased the draft and increased the load-carrying capacity. In barges or lighters, items such as hatch covers, partly formed of so-called "sliding beams", have also been made in light metal.

Light metals are still not used very much for the essential structural parts of private automobiles (with the exception of a few types such as the French Dyna-Panhard car, of which most of the structural parts are made of light metal). Essentially only the ornamental trim, visors, door stops, instrument parts and the like are made of light metal. However, light metal has been rapidly introduced into bus construction as well as into refrigerator trucks and transport

(Continued on p. 198)


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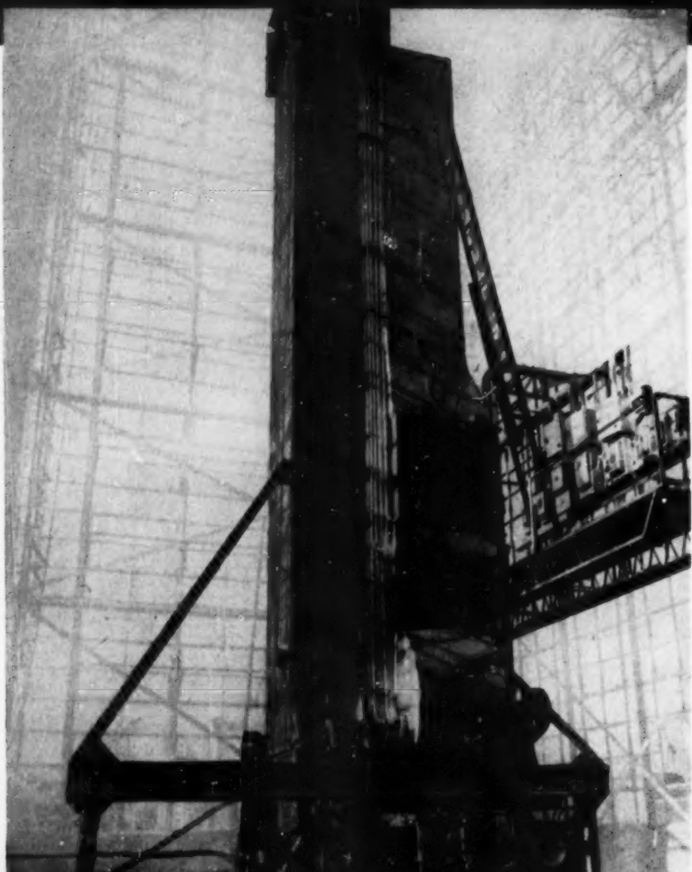

Aluminum in Europe

(Starts on p. 112)

trailers. A series of vehicle types has been developed in Europe which use the principle of stressed-skin construction and which, like aircraft, are distinguished by their low structural weight and high strength.

In railroad transportation it should be noted that light metal street cars have been in service in various European cities for several years and have proved quite satisfactory. A large number have been put into service in the London subway. Various railways, having obtained good results with light metal roofing on freight and passenger cars, have recently built entire cars and passenger trains out of light metal.

This development was stimulated by the "Talgo Train" built in the United States from plans by Spanish engineers. Aluminum forms the main structural material of this train, which has been operating on regular schedules in Spain for some years. The newest product in this field is the light metal sectional train designed for the German Railway Association, and first shown at the German Communications Exposition in Munich in 1953. It consists of five chair or sleeping cars, which, with end sections and engines, make a total length of about 325 feet.

Although these light metal trains have been equipped with every convenience such as air conditioning, individual sleeping compartments, dining and lounge car, the net weight of each train amounts to less than 700 lb. per ft. of over-all length – probably a record low value. The trains can go in either direction and are driven by four ordinary truck engines of 160 hp. each, installed in the head and rear sections.

Conclusion – Thus it may be seen that the aluminum industry in Europe, as well as in the United States and Canada, is progressing along parallel lines. Refining of the bauxite ore and the reduction of aluminum to metal are done by the same process; differences in equipment and plant arise principally from the size or scale of the operation. As is well known, German metallurgists made the original discoveries of the strong wrought alloys and their heat treatment. So many alloying possi-

(Continued on p. 200)

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Aluminum in Europe

(Starts on p. 112)

bilities exist that it is not surprising that the favored combinations vary somewhat in France, Germany, Italy, England and America, and are adapted to the commercial conditions existing in each country.

If one were to venture to list the outstanding European achievements of the last decade they would certainly include the mastery of the scrap recovery problem, the re-creation of civilian consumption to a volume which absorbs as much metal as at the wartime peak, the mitigation of intergranular corrosion and stress-corrosion by stabilizing heat treatments, and the perfection of the resin bonded joint for high strength at safe, low temperatures.

Swedish Steelmaking

(Starts on p. 108)

sponge iron, home scrap or scrap with known origin. On account of excessive cost, steelworks have one after another been forced to abandon the charcoal pig iron. Today they have to choose between coke pig iron and sponge iron (or more probably a combination of those two) together with high-grade scrap.

The acid bessemer process, with which the first successful blows were made in Sweden in 1858, was for a long time an important method used by our quality steel producers. The process was carried out in a different manner from what is normal in other countries today (where the carbon is blown down to low values and the analysis is obtained by additions before pouring). We used a specified pig iron with high manganese content in relation to the silicon, whereby a slag with suitable analysis was formed at such an early stage that blowing could be stopped and the steel tapped at the desired carbon content. In this way an excellent steel was produced.

After having been practically abandoned in the prewar decade, the acid bessemer has been re-adopted by the Fagersta steelworks, which now has erected 20-ton converters. Practice at Fagersta resembles the duplexing used in other countries. Part of the pig iron is converted to a raw steel which afterwards is finished in other types of furnaces. Phosphorus and sulphur contents are already low in the pig iron, and the nitrogen content can be kept at a sufficiently low level by adding ore during the blow, or by tilting the vessel toward the end of the blow.

The acid openhearth process, as it is carried out in Sweden, has special possibilities for a steel of both uniform and high quality. A characteristic of our process is that the temperature is raised before tapping high enough so that a certain amount of silicon is reduced back into the bath from the lining.

Another typical feature is the high pig iron percentage; the silicon content of the charge is consequently also high, which in any event would result in a considerable silicon residual in the bath after melt-down. This is of advantage, since the start of the boil is thus retarded until the bath reaches a still higher temperature, and this completely avoids any disturbing foaming; a lively and ordinary boil is obtained from the very beginning. In order to accelerate the eventual oxidation of silicon and thereby also the temperature rise, we have lately resorted to oxygen lancing during this period, and this cuts the time per heat by about 10%.

The process in Sweden is carried out in relatively small units, for it has been found that the process – and thereby the steel quality – can be kept under closer control in small furnaces. For a long time the optimum charge was considered to be 20 tons at a maximum, but more recently the upper limit has been increased to 30 tons – which today is the largest unit in operation. The furnaces are exclusively oil-fired, which has improved the heat economy over the use of producer gas. Production in the 30-ton furnace, melting cold charge, averages a little more than 3 tons per hr.

Some improvements in furnace design have also been made. At one steel plant a radical test was carried out in lining the whole "acid" furnace – except, naturally, the hearth bottom – with basic brick. The idea was to shorten the time, tap to tap. This experiment failed, not on account of the basic lining in itself, but because the furnace in question was not sufficiently buck-stayed and armored for basic brick. The idea will probably be taken up again.

(Continued on p. 202)

Swedish Steelmaking

(Starts on p. 108)

Basic Steel – Almost all Swedish basic openhearth is classed as commercial steel, and the process is operated along conventional lines. When "high-grade" steel is made, a higher percentage of pig iron is charged and the quality of the scrap is closely scrutinized.

The electric steel process, as is shown in the diagram, Fig. 2, now makes more steel than any other in Sweden. It is used extensively for commercial steels as well as for high-grade. Furnaces most recently built have been of traditional design with three electrodes in delta, and are generally intended for 25 to 30-ton charges. Even larger furnaces are now under construction. According to American practice the transformer capacity and voltage have been gradually increased in order to cut down melting time. Electrodes are usually graphite, but continuous Söderberg electrodes are also common and have proved economical when intelligently used.

A disadvantage in electric steelmaking is that the bath movement is often insufficient during those periods in which no carbon monoxide is being generated – as, for instance, when the steel is covered with a reducing slag or when alloying elements are being added. In order to improve conditions in this respect, a low-frequency stirrer of the Dreyfus-Asea type has been installed at several furnaces. The induction coil, attached under the furnace bottom, causes a lively movement in the bath which speeds up reactions and facilitates the distribution of alloying elements to a completely homogeneous bath. The electrodynamic forces furthermore direct the bath movement at the surface toward the furnace door, thereby making it possible to slag-off more easily and efficiently.

The high-frequency furnace has also grown in importance for high-grade steel production. It probably has come to a much wider use in Sweden, relative to other furnace types, than in any other country. A large number of 5 to 8-ton units are in operation. A year ago an installation with 12-ton furnaces (3400 kw.) was started at the Bofors steel plant (Fig. 4, p. 111). In this plant – as is usually the case – two furnaces are operated in tandem; one can be used with low power to keep the steel at temperature while the charge is being melted in the other. All furnaces larger than 2 tons have acid linings, since a durable basic lining has not been found for larger units.

High-frequency furnaces have shown themselves to be especially suitable for melting low-carbon stainless scrap, since there is no risk of carburization. They are also preferred for quality steel in general, if suitable raw materials are at hand so that no other refining than possibly a short boil is needed. One great advantage is that the steel analysis and the temperature can be held within very close limits.

Pouring practice follows, on the whole, the same trends as in other countries. In quality steel production, top pouring is probably more extensively used than elsewhere.

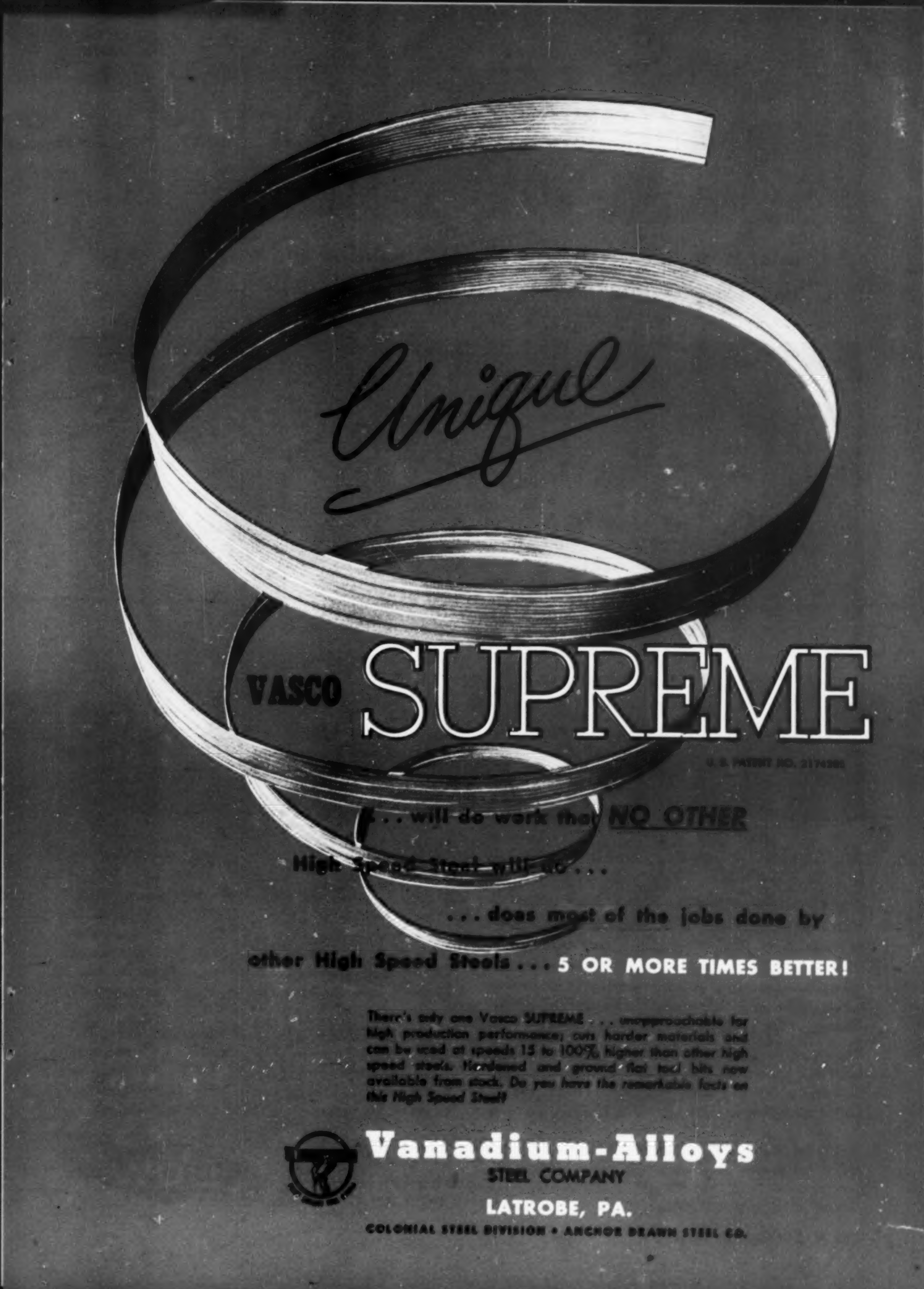
Interest in continuous casting is great in our country, which is natural, as most steelworks operate with small units and with a very divergent production program. The first full-scale installation for continuous casting is being erected at Nyby.

CONCLUSIONS

This somewhat cursory survey of the Swedish quality steel industry makes it clear that, in spite of a relatively modest production level, we use various steel production methods. No single process can be said to be the dominating one. This is shown very clearly in the statistics of Fig. 2 tracing the development of the different steelmaking process since the beginning of the century.

Again, ore reduction, although mainly in coke blast furnaces, is done in other equipment as well.

The prime reason for this diversified development is that Swedish metallurgists have had to try all possible ways in order to keep our favorable position on the world market as a producer of high-grade steel, even when the excellent raw materials we once possessed gradually deteriorated. A valuable asset remains in a century-old experience in high-grade steelmaking and the possession of skilled workers, trained in the tradition of excellence.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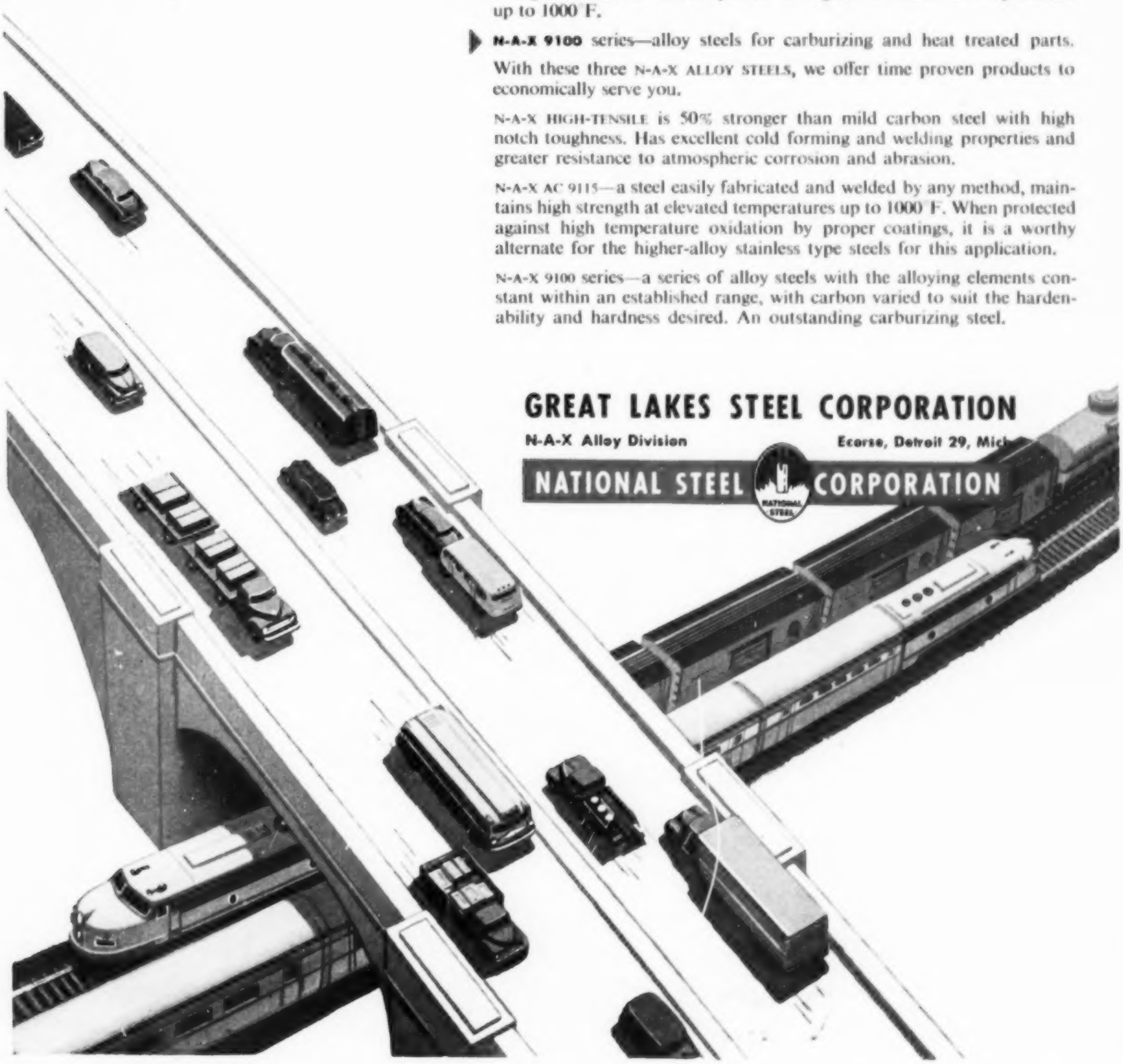

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Blacken

copper, zinc, steel

the SURE way with . . . ENTHONE

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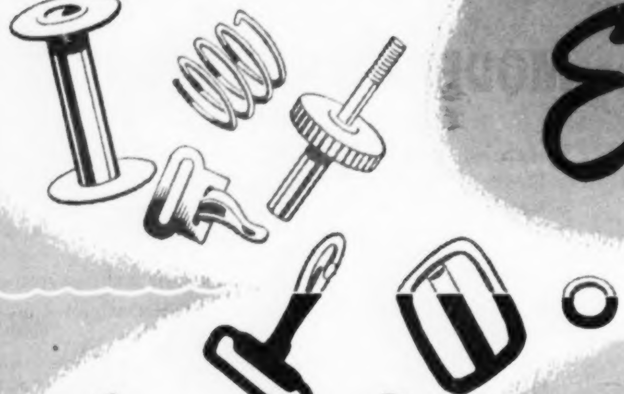

Enthone, with years of experience, has accumulated a storehouse of information on the right way to blacken metals. This knowledge is always available to our customers through our Service Department.

EBONOL "S" Processes for blackening steel to produce jet-black oxide coatings. Simple and economical to operate. Operating temperatures: EBONOL "S", 285-290°F., EBONOL "S-30", 295-305°F.

EBONOL "C" The quality black for copper and brass that meets all military specifications.

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EBONOL "Z-80" A blackening process for zinc and zinc base alloys. Operates at room temperature.

WRITE US FOR ANY NEEDED INFORMATION OR ADVICE ON ANY BLACKENING PROBLEMS

*REG. TRADEMARK

U.S. PATENT NOS. 2,364,993, 2,460,896, 2,460,898, 2,481,854.

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THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

HAPPY NEW YEAR!

HIGHEST AMONG THE REWARDS AND SATISFACTIONS OF THE PAST YEAR WE, OF GENERAL ALLOYS, RATE THE FRIENDSHIP AND CONFIDENCE OF THE MEN OF METALS WITH WHOM WE HAVE HAD THE PRIVILEGE OF ASSOCIATION DURING THE PAST THIRTY-THREE YEARS.

1954, A Bigger Year in G. A. Research and Development

Next most satisfying is our 1953 crop of ALLOY CASTING PROGRESS. This has grown from many "seeds" (some planted long before 90% of the foundries now casting alloy had made a pound). Since planting, they have been thinned, fertilized, cultivated and developed by increasing RESEARCH AND DEVELOPMENT.

Some principal objectives of such developments have been to evaluate, interrelate and combine in our product (1) DESIGN—From a sound mechanical, thermal, physical and chemical evaluation of the service requirements and operating conditions, design must be individually *Engineered* for each application; (2) ANALYSIS—Selected for the combination of strength, fatigue and corrosion resistance required, and (3) CASTING DESIGN-PROCESS TECHNOLOGY—The pattern, core boxes, rigging and gating are designed, and the thermal path controls and pouring temperature charted and specified for each individual configuration, so that the solidifying metal, as the casting is "born to size" as a high integrated cast component, is controlled as to *structure, grain size, residual stresses, dimension* and *finish*.

Such *comprehensive engineering* produces products to extend General Alloys' leadership in producing the most *functional tools* for the processes in which they serve. Such GA products have established thousands of unequalled records of loads carried and service life and hours run.

Decreasing Inflation?

Indications are that 1954 over-all alloy casting production may fall 10 to 16% below the recent all-time highs of alloy production, if predicted trends in some industries continue at a notch or two below the highly inflationary trend of combined war and defense economy (plus that election-year "political boost.") That is a sound sign, a good omen for stability and progress.

Nickel, other raw materials and labor are now at all-time highs in cost. There are still, however, a number of ways to cut the cost of alloy castings, cut corners in process, increase the scrap content and cheapen the product without reducing the nickel-chrome content. Some may cheapen alloy castings in quality and price, in the hope of "swimming upstream" to retain 1952 sales volume. This may be a "costly economy" in shutdowns and service life. G. A. will not. Considering replacements and service life, exclusive of the superior working function of General Alloys' *Engineered designs*, history has proven without a doubt that, in alloy process components, (a) The best is not too good, (b) The quality product is cheaper in overall cost, and (c) The best alloy casting service records in U. S. industry *for 34 years* are made by G. A. products.

Accurate Records of Alloy Life Give You The "Low-Down"

General Alloys' products have steadily, *and recently, been improved* and refined with resultant *improved service life* by a score or more of technological improvements developed largely from our R&D. Most of such process improvements add to cost, but return in added service life from averages three to ten times the cost. These improvements in process (several of them are in use, but have not been announced while patents are pending) have been made with no increase in price and have brought savings to users *which are clearly shown wherever records are kept. Only General Alloys* is able to offer you these increments of alloy improvement. We expect 1954 to be a good G. A. year.

Those who offer for *less* have *less* to offer. It has always been possible to buy alloy castings at a variety of prices. Seldom does a buyer get more than he pays for. The only safeguard plant management can erect against price-buyers and "cheap" producers (the "chicken and the egg") is to *keep accurate alloy life* records in the heat-treat, know the performance of each product purchased, *establish life expectancies per-dollar-cost on quality alloy*, and see that they are maintained. It generally takes two to five years of service life to rate an alloy.

H. H. HARRIS

An "Aditorial" by the President of GENERAL ALLOYS COMPANY.

Dr. Kinsey Didn't Check With Our "Aunty Snowball"

The "scientific literature of the arts of casting metal, and of statistical love, are confusing. The "apparent simplicity is, often, merely the misleading coherence of complexity."

We have been too busy to read Dr. Kinsey's latest report. We did read the comment and criticism in LIFE. Both ignored, we believe, a realistic statistic we learned at the age of nine.

Our education in the M & F Dept. occurred at Palm Beach, Florida where, during successive winters, we were entrusted to the wise and loving ministrations of a fine old Georgia Mammy, who made "Aunt Jemimah" look like a bleached blonde. There were 180 pounds of blue-black, immaculate Aunty Snowball which included more weight of heart and horse-sense than you could find in most PTA's.

We didn't understand or appreciate the sublimely satisfactory difference between boys and girls and had been asking juvenile questions which were expertly evaded for days. Finally, Aunty Snowball reached a momentous decision. With furrowed brow she remarked: "Wal, honey, yo' is ole enuf so as we-all kin quit reconnoiterin' 'roun' de truf. Ah's done tole yo' some li'l white fibs. De gawd's truf is dat li'l boys *ain't* made of snakes 'n snails 'n puppy dog tails, and li'l gals *ain't* made of sugah 'n spice 'n ev'rythin' nice. *Dey's bof sinnahs* wi' de orig'nal sin, and dey sins mo' when de grows up. Now, honey, it done take two-uns t'make a sin, so dey's gotta be jes' as many li'l gals a-sinnin' as li'l boys, or dem as do sin, sins double." Heaving a ponderous sigh that shook an acre of starched white apron, she continued: "But jes' yo-all remembah, chile, de nice li'l gals when dey's naughty is twice better'n de naughty li'l gals when dey's nice."

Women continue to be a riddle. We aren't qualified to judge Dr. Kinsey's femographics, but we have a hunch that Aunty Snowball got the answer first, and that it will probably survive statistical research.

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

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FAHRALLOY . . .

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NO SUBSTITUTE for FAHRALLOY SERVICE

IN addition to the sound engineering counsel that Fahralloy has rendered its customers for over 20 years, one of the most important things that has helped the company build the enviable reputation it enjoys in the alloy field is an intangible called, out-of-the-ordinary service. The service isn't just any one thing, it's a combination of many. Net result— Fahralloy has come to be known for complete dependability! Fahralloy service has even gone so far in some instances of emergency to provide delivery by air with its company plane pictured above. Naturally, this is the exception rather than the rule, but it does show to what extent Fahralloy goes to provide that extra something in service . . . the extra something that assures complete customer satisfaction. There's no better time than now for you to experience it for yourself.

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DO YOU HAVE *tough* X-RAY INSPECTION JOBS?

At the American Steel Foundries' plant in Newark, New Jersey, heavy steel castings are easily X-rayed due to equipment *flexibility.*

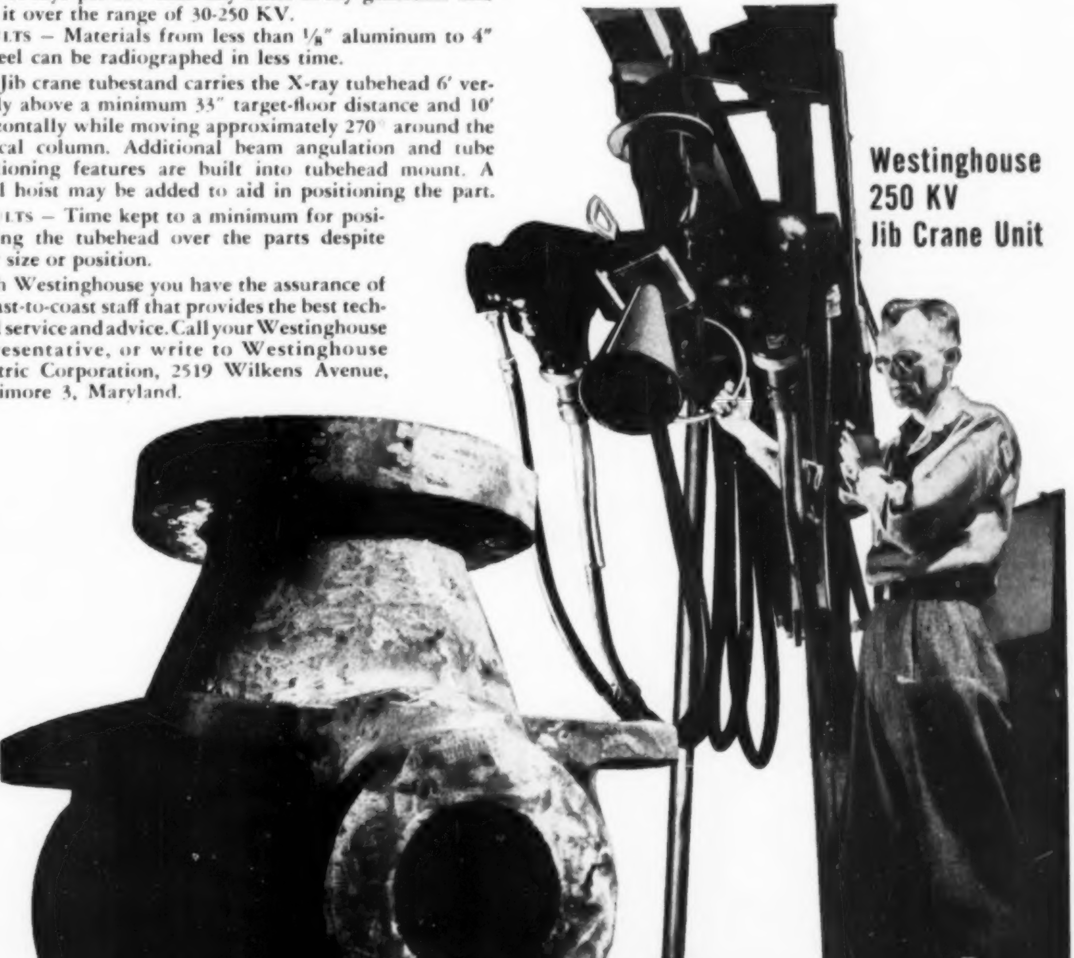
1 – *Constant Potential* high voltage generator produces more X-rays per KV than any other X-ray generator and does it over the range of 30-250 KV.

RESULTS – Materials from less than 1/8" aluminum to 4" of steel can be radiographed in less time.

2 – Jib crane tubestand carries the X-ray tubehead 6' vertically above a minimum 33" target-floor distance and 10' horizontally while moving approximately 270° around the vertical column. Additional beam angulation and tube positioning features are built into tubehead mount. A small hoist may be added to aid in positioning the part.

RESULTS – Time kept to a minimum for positioning the tubehead over the parts despite their size or position.

With Westinghouse you have the assurance of a coast-to-coast staff that provides the best technical service and advice. Call your Westinghouse representative, or write to Westinghouse Electric Corporation, 2519 Wilkens Avenue, Baltimore 3, Maryland.



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Many metal fabricators credit their substantial production improvements to use of Scovill Continuous-Cast Brass Mill Products . . . less down-time . . . fewer rejects . . . better tool and die life . . . superior finish . . . or successful running of a particularly tough job.

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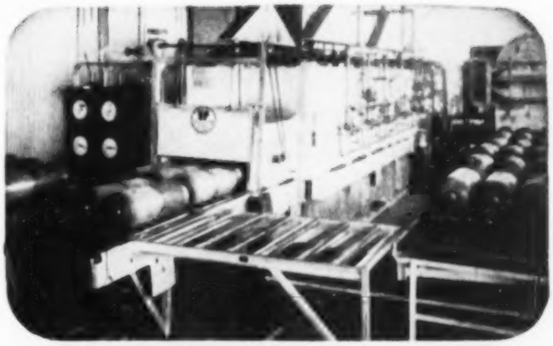

Compressed gas cylinders or tanks are continuously normalized and annealed—scale-free in EF gas fired furnaces.

Heavy castings, plate, weldments and other products are heat treated in these EF furnaces. Gantry cranes simplify loading, unloading and quenching.

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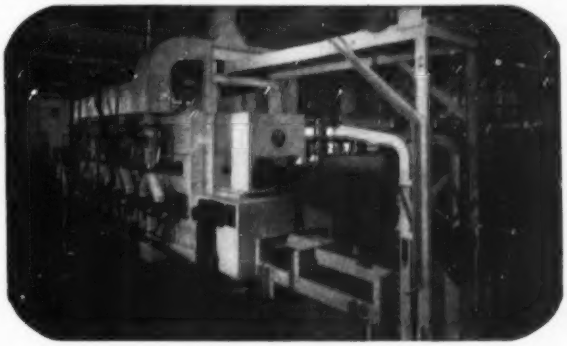
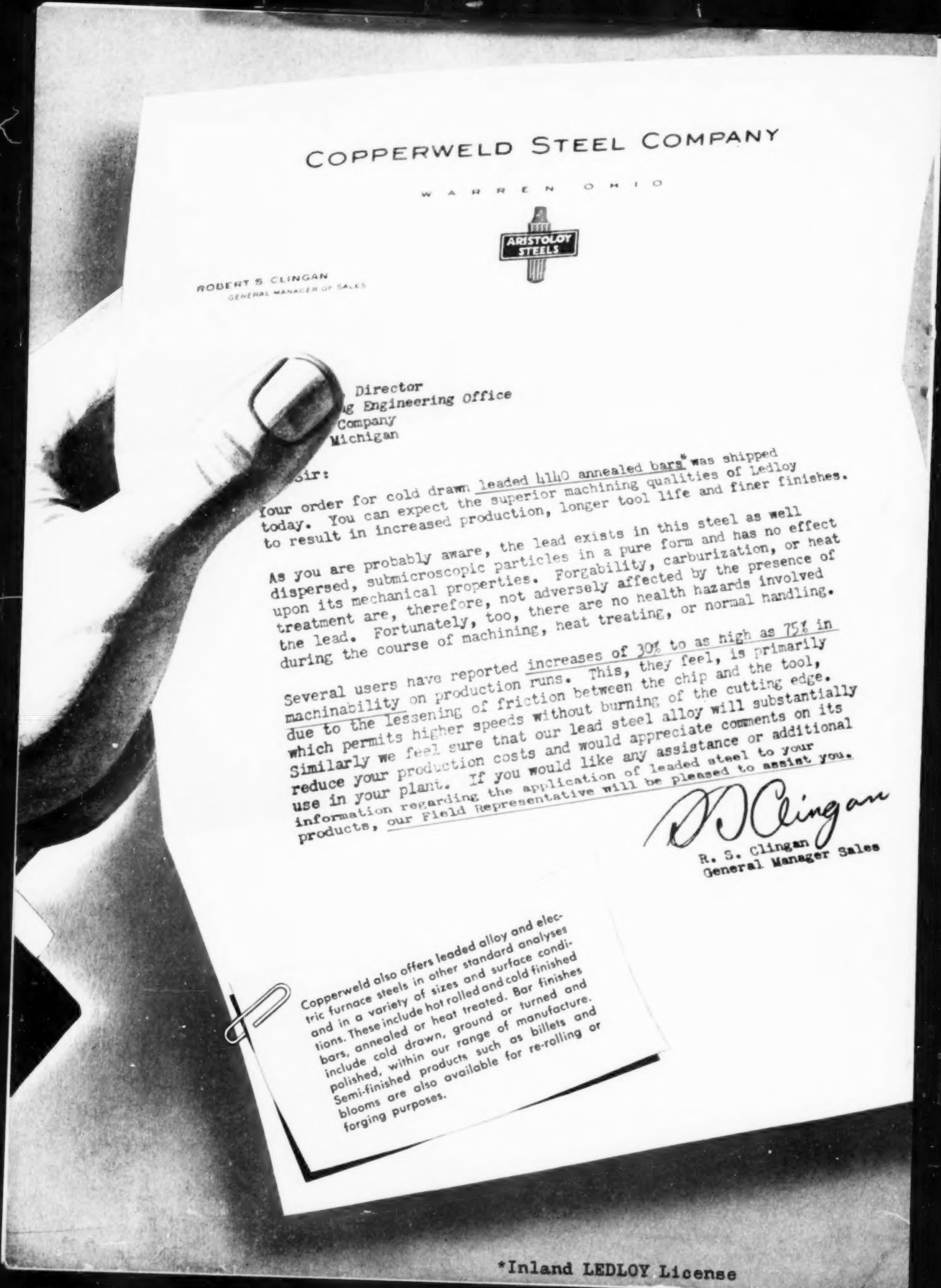


Bolts, springs and other products are scale-free heat treated in EF continuous chain belt conveyor furnaces similar to the one at right. 11 sizes—to handle from 125 to 2000 lbs. or more per hour. Hundreds are in operation.



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GENERAL MANAGER OF SALES

Director
g Engineering Office
Company
Michigan

Sir:

Your order for cold drawn leaded 4140 annealed bars* was shipped today. You can expect the superior machining qualities of Ledloy to result in increased production, longer tool life and finer finishes.

As you are probably aware, the lead exists in this steel as well dispersed, submicroscopic particles in a pure form and has no effect upon its mechanical properties. Forgability, carburization, or heat treatment are, therefore, not adversely affected by the presence of the lead. Fortunately, too, there are no health hazards involved during the course of machining, heat treating, or normal handling.

Several users have reported increases of 30% to as high as 75% in machinability on production runs. This, they feel, is primarily due to the lessening of friction between the chip and the tool, which permits higher speeds without burning of the cutting edge. Similarly we feel sure that our lead steel alloy will substantially reduce your production costs and would appreciate comments on its use in your plant. If you would like any assistance or additional information regarding the application of leaded steel to your products, our Field Representative will be pleased to assist you.

R. S. Clingan
R. S. Clingan
General Manager Sales

Copperweld also offers leaded alloy and electric furnace steels in other standard analyses and in a variety of sizes and surface conditions. These include hot rolled and cold finished bars, annealed or heat treated. Bar finishes include cold drawn, ground or turned and polished, within our range of manufacture. Semi-finished products such as billets and blooms are also available for re-rolling or forging purposes.

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